FINAL REPORT TO THE CALIFORNIA AIR RESOURCES BOARD

UNDER AGREEMENT ARB-2-704

DEVELOPMENT OF A SYSTEM FOR EVALUATING AND REPORTING ECONOMIC CROP LOSSES CAUSED BY AIR POLLUTION IN CALIFORNIA

II. YIELD STUDY

IIA. PROTOTYPE OZONE DOSAGE-CROP LOSS CONVERSION FUNCTION

by

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ABSTRACT

A prototype assessment method (dosage-crop loss conversion function) for determining sweet corn losses from ozone was developed utilizing the functional relationship between the crop and ambient ozone dosages. Environmental variables were tested but were not observed to significantly influence sweet corn yield. The procedures for the development of this conversion function could be applied to develop conversion functions for other crops.

Fumigation studies compared two different regimes of ozone fumigations and indicated that frequent short-term exposures had a far greater effect on yield reductions than less frequent exposures of longer duration. Total dosages were comparable but corn and tomatoes fumigated 1½ times a week for 6 hours did not show significant reductions in yield.

Nutritional analyses of 1972 PAN (peroxyacetyl nitrate) and ozone fumigated crops were completed. PAN did not appear to influence significant changes in the levels of most nutritional constituents in harvested samples. Ozone was found to reduce levels of carbohydrates and solids in corn and tomatoes. Vitamin levels were observed to have a varied response specific to certain crops. Overall, ozone was observed to have a much greater effect on nutritional levels than PAN.

This report was submitted in fulfillment of Agreement No. ARB - 2-704 by the Department of Food and Agriculture under the sponsorship of the California Air Resources Board. Work was completed as of 30 June 1974.

Varieties of pole tomato, carrot, leaf lettuce, cabbage, strawberry and orange were also studied in integrated programs of fumigation and field study but were not selected for developing the ozone-dosage crop loss function because of a number of problem areas. Many were observed to be susceptible to ozone injury and were found to have lower yields but logistical, geographical or numerical considerations precluded using them.

TABLE OF CONTENTS

MAPS

TABLES

Page

FIGURES

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Many students in the Work Study Program at the University of California assisted in providing the field labor throughout this project.

Special thanks is extended to the many local growers who participated in the program.

CONCLUSIONS

A prototype ozone dosage-crop loss conversion function was developed which has the potential to standardize field crop loss assessments. This methodology utilized the functional relationship which exists between pollutants and crops under field conditions to predict crop yield reduction. The developmental procedures necessary for production of such conversion function have been tested and the production of operational ozone dosage-crop loss conversion function for sweet corn and alfalfa will be undertaken in the 1974 program.

The frequency of ozone exposure appeared to be as critical a factor as total dosage in long-term fumigations. A greater number of relatively short-term fumigations had a more pronounced effect on plants in their production than fewer exposures of greater duration. The ozone fumigation study of sweet corn and tomatoes in 1972 and 1973 illustrated this effect.

There was no discernible trend in the effects of PAN on nutritional levels within the tested samples. Generally, PAN appeared to have little effect on the nutritional constituents within the six crops.

Ozone appeared to have a significant effect on the nutritional levels of many test crops. Reductions in carbohydrates solids and a great number of nutritional constituents were observed. PAN did not affect as many different constituents.

Multiple harvest crops should be studied singly as a large amount of labor would be required to harvest them. Field plots established in commercial fields were impossible to isolate from harvest crews in spite of every possible precaution.

The AMBI stations were successful in monitoring ozone and PAN for the second successive year. Significant correlations between pollutant dosages and plant injury were observed for both ozone and PAN but no climatological variables tested proved to have a significant influence.

RECOMMENDATIONS

Ozone dosage-crop loss conversion functions should be developed for the major agricultural crops in California. They would provide the means to develop the first standardized crop loss estimates and would be instrumental in developing data for the establishment of viable secondary air quality standards.

Further work should be undertaken to delineate the extent to which exposure frequency can influence fumigation results. Experiments designed to detect foliar injury may not be adversely affected but any long-term fumigation study involving yield records could easily be biased by this factor.

A PAN monitoring study should be undertaken to determine injury thresholds for susceptible crops. This type of monitoring should use instruments as accurate dosages would be desirable. An AMBI study could map areas of high ambient dosages but would not provide the needed injury thresholds.

INTRODUCTION

Foliar injury has historically been the criterion used in determining the susceptibility of plants to oxidant air pollutants (1, 2, 4). Possible yield and quality effects have been assumed to occur as a result of foliar injury but few investigations have probed this relationship. Heavily injured crops have been reported to produce yield reduction (3, 5, 8, 9) but much more information is necessary to determine the functional relationship between foliar injury and yield reduction if threshold concentrations of ambient oxidants are to be basic to the establishment of viable secondary air quality standards.

The initial quality phase of this study (6) concentrated on possible oxidant-induced reductions in crop quality. Long-term fumigation studies indicated little oxidant effect on the quality of the non-leafy study crops but demonstrated significant yield reduction. Correlations of ambient ozone dosages with quality evaluations of field grown produce tended to bear out the fact that most quality parameters were not directly associated with the ambient dosages.

The long-term ozone fumigations conducted in the 1972 quality study were relatively short (3-hours) in duration but scheduled on alternate days with little time for plant recovery. The significance of the frequency of exposures compared to total exposure dosages was questioned in relation to plant effects. Would plant recovery negate or minimize the effects of foliar injury on yields if given sufficient time? Accordingly, the 1973 long-term fumigations were designed to incorporate longer exposure periods (6-hours) but given at less frequent intervals (1.5 exposures per week). A comparison of the two types of fumigation design will be evaluated in the Discussion Section.

The 1973 yield phase included the same seven crops used in 1972 but concentrated development efforts on a single selected crop exhibiting the greatest potential. Developmental procedures were therefore restricted to Golden Jubilee sweet corn but all experimental results for each of the other test crops are presented in their respective chapters.

The nutritional analyses of the 1972 harvested long-term ozone and PAN (peroxyacetyl nitrate) test crops is included in this report within sections devoted to the specific test crops. The analyses were completed by the Western Regional Research Laboratory, United States Department of Agriculture, Berkeley, California, which routinely runs samples for nutrient contents.

This report presents the prototype ozone dosage-crop loss conversion function developed from the 1973 Golden Jubilee sweet corn data and summarizes the results of the yield studies of all seven test crops. The dosage-loss conversion function is not yet fully operational but our research clearly illustrates the potential of such an assessment tool. The next phase (1974) will deal with the refinement methodology and the production of an operational ozone dosage-crop loss conversion function for sweet corn and alfalfa.

DESIGN

This project incorporates several components integrated into a functional model to produce the desired methodology for economic assessment of air pollution damage to agriculture (Figure 1). The project's scope, in a geographical and physical sense, is outlined in the following discussion. Basic procedures used and systems developed are also described.

Study Area

The South Coast Air Basin, including Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties, was selected as the study area. County Air Pollution Control Districts of the respective counties have provided ambient oxidant data from a network of established instrument monitoring stations. A key to the stations used by this program is listed in Table 1. Actual geographical locations are presented in Map 1.

The National Weather Service and several military installations provided a source of temperature and humidity data. A key to the stations used by this program is listed in Table 2. Actual geographical locations are presented in Map 2.

Test Crops

The same six table crops and one tree crop were continued in the yield study. Varieties were selected on the basis of popularity and distribution throughout the air basin. New varieties of cabbage and lettuce were selected in an attempt to increase sensitivity over the resistant strains used in the quality phase. The list of study crops includes:

1. Golden Jubilee sweet corn
2. H-11 pole tomatoes
3. Emperator #58 carrots
4. Greenback cabbage
5. Dark green Boston leaf lettuce
6. Tioga strawberries
7. Valencia oranges on troyer rootstock

Test crops are seasonally grown and although some overlap exists between seasons for Tioga strawberries and Valencia oranges, both were arbitrarily defined as falling within one of the two selected growing seasons. Golden Jubilee corn, H-11 tomatoes, Emperator #58 carrots and Valencia oranges were designated as spring test crops and Greenback cabbage, dark green Boston lettuce and Tioga strawberries as fall test crops.

Each field location within the study area was assigned an identification number (Table 3). Actual geographical locations for the spring test crops are given in Map 3 and fall test crops in Map 4.

Air Monitoring Biological Indicator System

Few regions within California are as well monitored for ambient air pollutants as the South Coast Air Basin. If the assessment methodology developed by this program was to be implemented without the tremendous expenditure of funds necessary to set up an instrument monitoring network, the development of an inexpensive mobile monitoring system was imperative. To this end an air monitoring biological indicator (AMBI) system, utilizing selected oxidant-sensitive indicator plants, was developed and tested during the quality phase. A replicate year of testing was implemented during the 1973 phase. This system was correlated with actual ambient oxidant levels recorded by the instrument monitoring stations. A description of this system is presented in the Ambient Ozone and Climatological Data Monitoring chapter of the Experimental Section.

Field Studies

Field and test plots designed to determine possible yield reductions associated with ozone were set up in the South Coast Air Basin. Three test plots, each growing the full complement of study table crops, were grown and maintained by project personnel and used as points of reference for the inland and coastal production areas. Unfortunately, the Moreno spring test plots were discontinued due to hardpan soil condition which caused salt injury and an infestation of Fusarium wilt. Fall test crops were successfully grown at a new location on the field station.

Field plots, located in selected commercial grower fields, were sampled for yield differences. Only growers recommended by the staff of the County Agricultural Commissioners' offices were considered. Selection of the field plots was based on variety of crop planted and location within the study area.

All field plots were checked on a weekly basis during the growing season and harvested at a uniform age. Harvests were performed by project personnel and samples were weighed and measured on the same day. All field samples were stored in plastic bags prior to processing to maintain a minimal moisture loss.

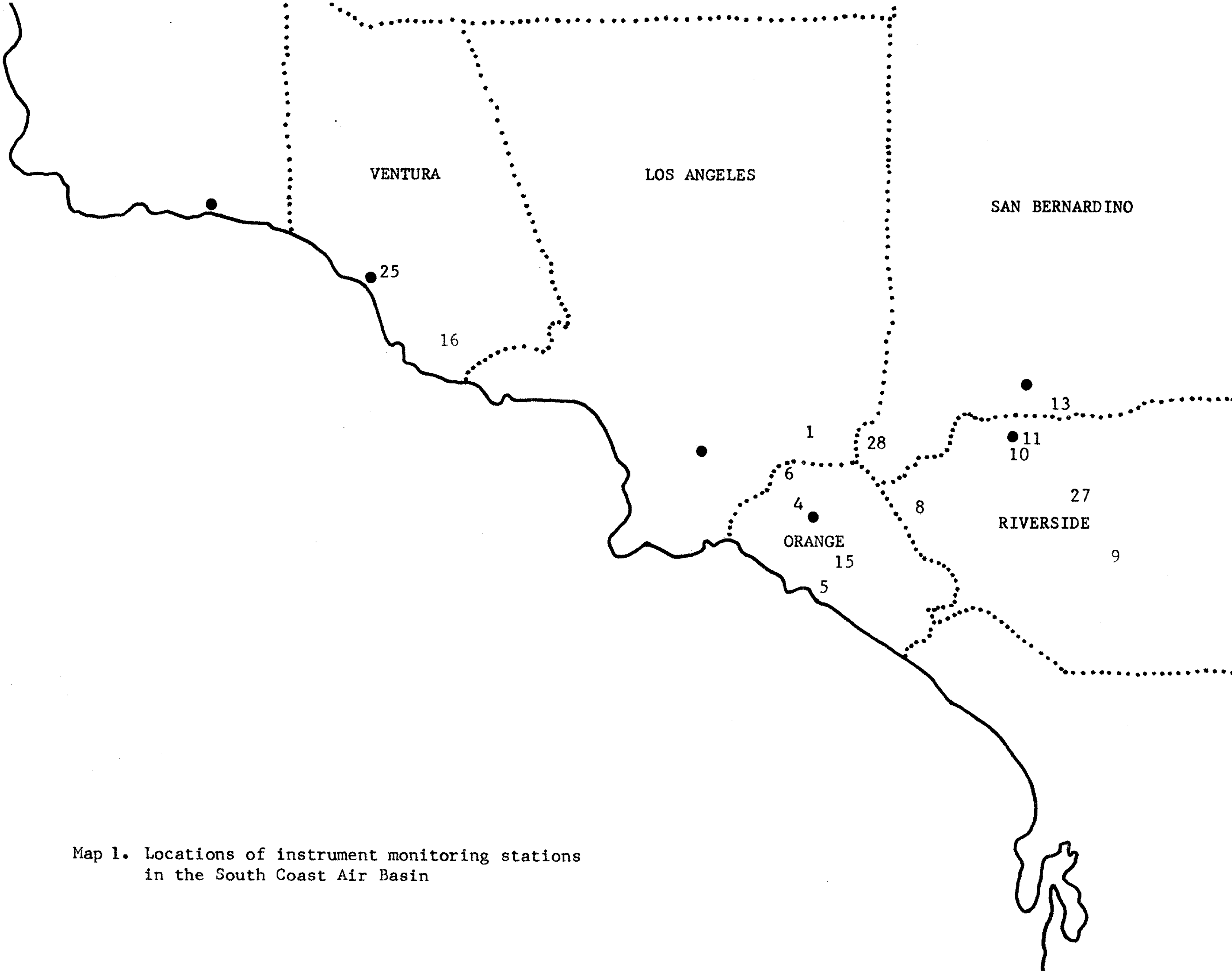
Statistical Evaluation and Analysis

All data from fumigations and from field plots was analyzed statistically to determine significance utilizing analysis of variance and Duncan's multiple range test. A statistical correlation was selected as the means of evaluating the association between ambient oxidants and crop yield reductions. If significant differences occurred between locations, a linear regression correlation was used to determine the level of significance.

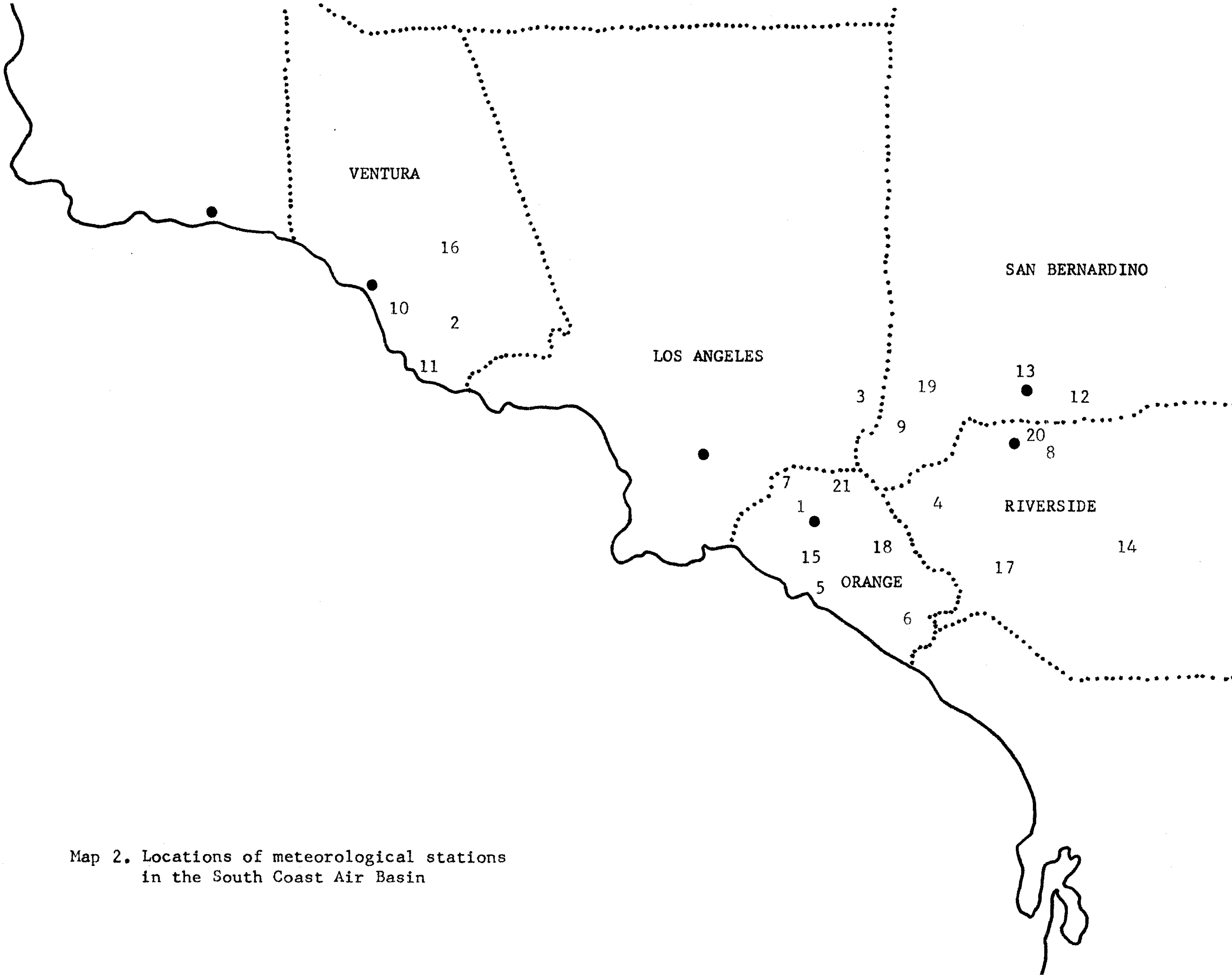
The total ambient oxidant dosages affecting the growth of crops was correlated, via a linear regression, with the evaluated mean quality. The level of statistical significance given each correlation measures the probability of a significant association between the evaluated quality and the total oxidant dosage present during growth. Such correlations cannot confirm these associations as would controlled experiments, but do indicate the probability at given confidence levels.

A multiple regression correlation was run to test the effect of the monitored variables on the productivity of the test crop. Total ambient ozone dosage, average seasonal relative humidity, average seasonal maximum temperature and average seasonal minimum temperature were correlated with crop productivity (unhusked ear weight) to determine the significant effects of each.

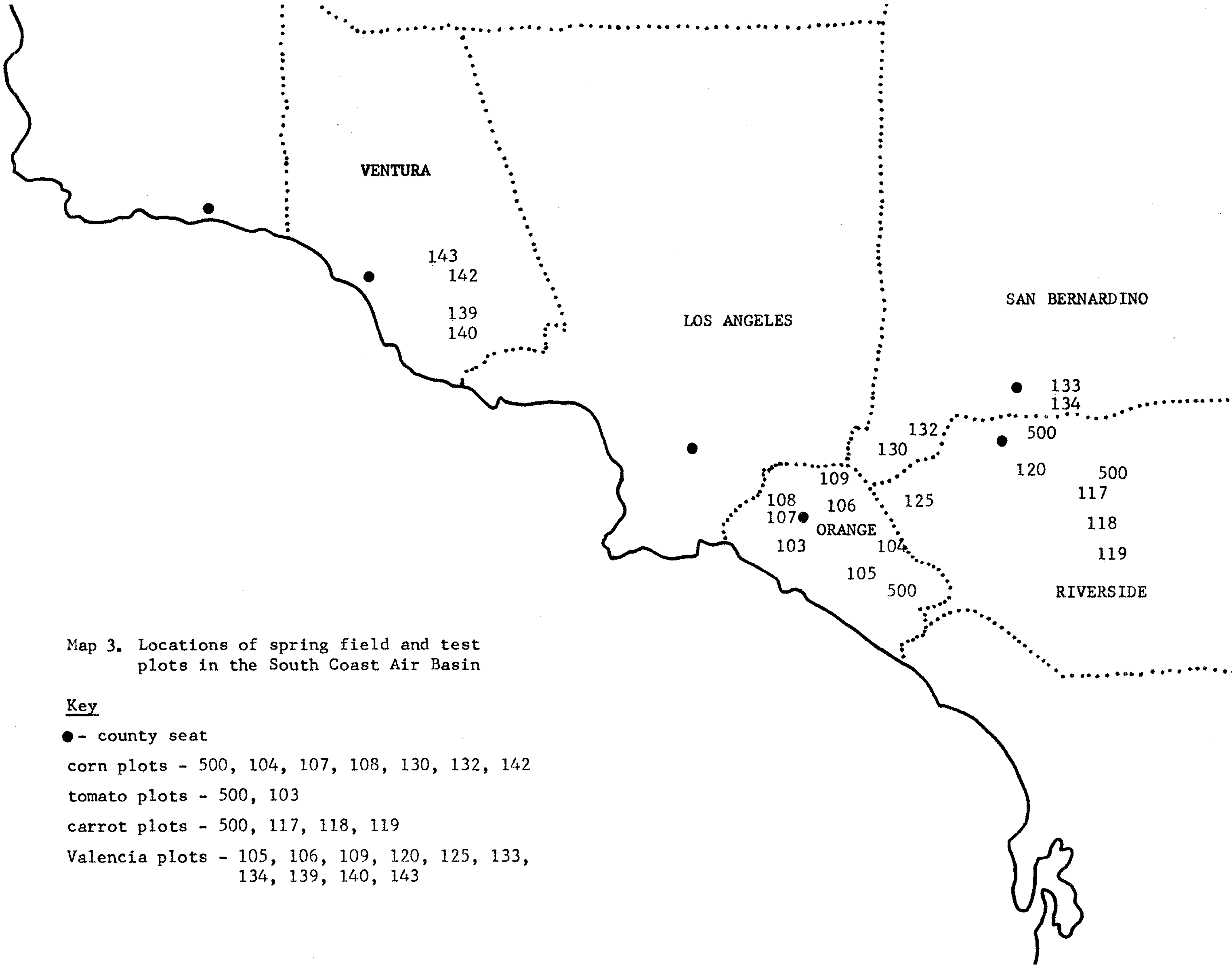
The correlations are presented in graphic form with their respective correlation coefficients and t-slopes included. The following notations of significance are also presented if applicable: * = 95%
** = 99%



Map 1. Locations of instrument monitoring stations in the South Coast Air Basin



Map 2. Locations of meteorological stations in the South Coast Air Basin



Map 3. Locations of spring field and test plots in the South Coast Air Basin

Key

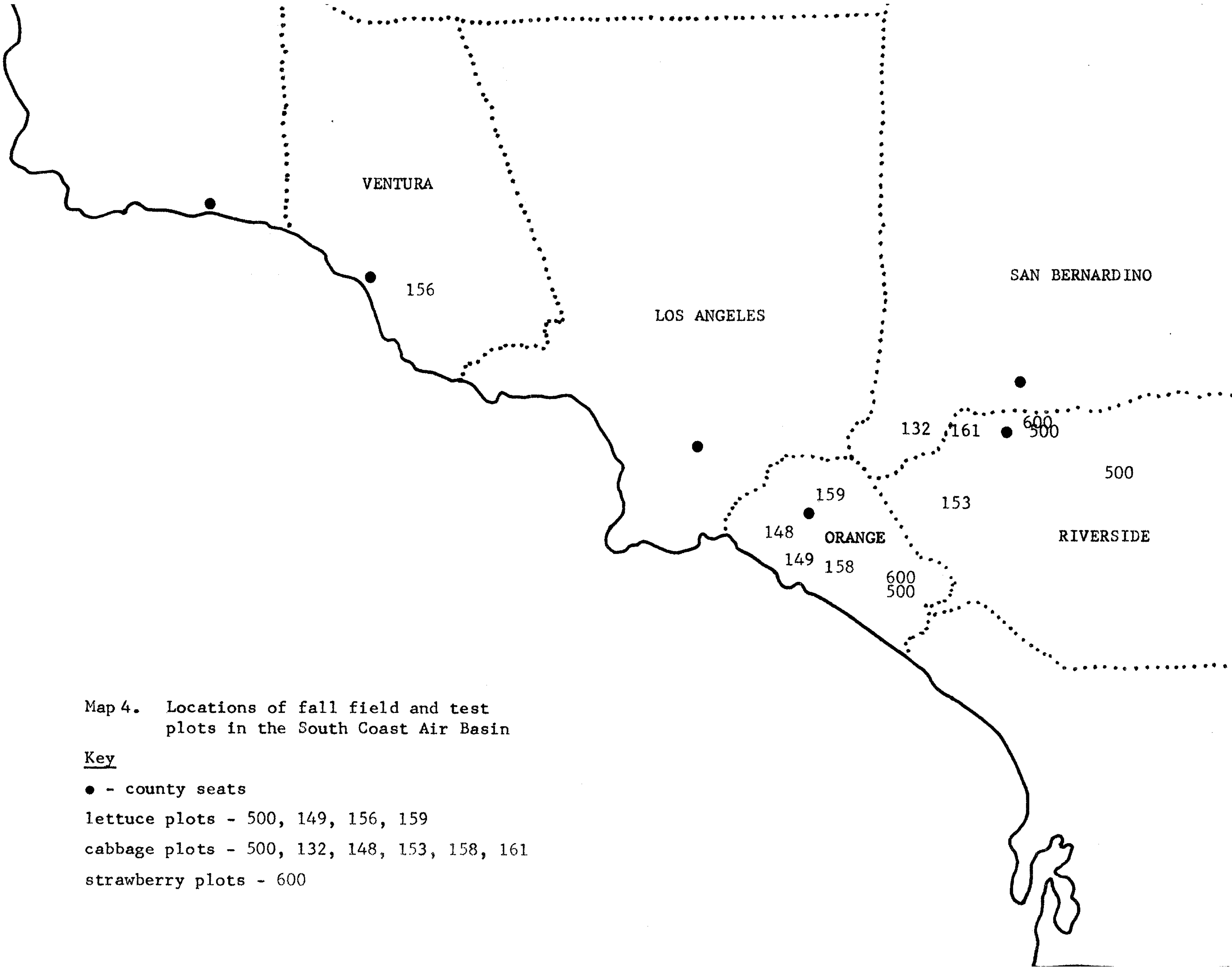
● - county seat

corn plots - 500, 104, 107, 108, 130, 132, 142

tomato plots - 500, 103

carrot plots - 500, 117, 118, 119

Valencia plots - 105, 106, 109, 120, 125, 133, 134, 139, 140, 143



Map 4. Locations of fall field and test plots in the South Coast Air Basin

<u>Key</u>

● - county seats

lettuce plots - 500, 149, 156, 159

cabbage plots - 500, 132, 148, 153, 158, 161

strawberry plots - 600

Table 1. Identification key to A.P.C.D. oxidant instrument monitoring stations utilized in the South Coast Air Basin.

Identification No.	Monitoring Station
1	Azusa
4	Anaheim
5	Costa Mesa
6	La Habra
27	Moreno
8	Corona
9	Hemet
10	Riverside
11	U.C.R.[1/]
13	Redlands
28	Chino
15	South Coast Field Station[2/]
16	Camarillo
25	Ventura

1/ Instrument station run by the Statewide Air Pollution Research Center, University of California at Riverside.

2/ Instrument station run by the Air Pollution Methodology Program.

TABLE 2. Key to Meteorological Stations

1.	Anaheim
2.	Camarillo
3.	Claremont
4.	Corona
5.	Costa Mesa
6.	El Toro
7.	La Habra
8.	March AFB
9.	Ontario
10.	Oxnard
11.	Pt. Mugu
12.	Redlands
13.	San Bernardino
14.	San Jacinto
15.	Santa Ana
16.	Santa Paula
17.	Sun City
18.	Tustin
19.	Upland
20.	U.C.R.
21.	Yorba Linda

Table 3. Identification key to field and test plot locations and harvest data.

I. Golden Jubilee Corn

Identification No.[1/]	Location
104	Orange Co.
107	" "
108	" "
130	San Bernardino Co.
132	" " "
142	Ventura Co.
501	S.C.F.S. Test Plot Set #1
502	" " " " #2
503	" " " " #3
504	" " " " #4
505	U.C.R. Test Plot Set #1
506	" " " " #2
507	" " " " #3
508	" " " " #4
509	Moreno Test Plot Set #1
510	" " " " #2
511	" " " " #3

II. H-11 Tomatoes

514-538	Orange Co. Test Plot
539-555	U.C.R. Test Plot
556-573	S.C.F. Test Plot

III. Emperator #58 Carrots

117	Riverside Co.
118	" "
119	" "
512	U.C.R. Test Plot
513	Moreno Test Plot

IV. Dark Green Boston Lettuce

149	Orange Co.
159	" "
156	Ventura Co.
584	S.C.F. Test Plot
585	Moreno Test Plot
586	U.C.R. Test Plot

1/ Identification numbers consist of 3 digits. The 500 series refers to test plot harvests only. The 100-499 series refers to commercial field plots only.

V. Greenback Cabbage

Identification No.	Location
132	San Bernardino Co.
148	Orange Co.
158	" "
161	Riverside Co.
153	" "
589	S.C.F. Test Plot
588	U.C.R. Test Plot
587	Moreno Test Plot

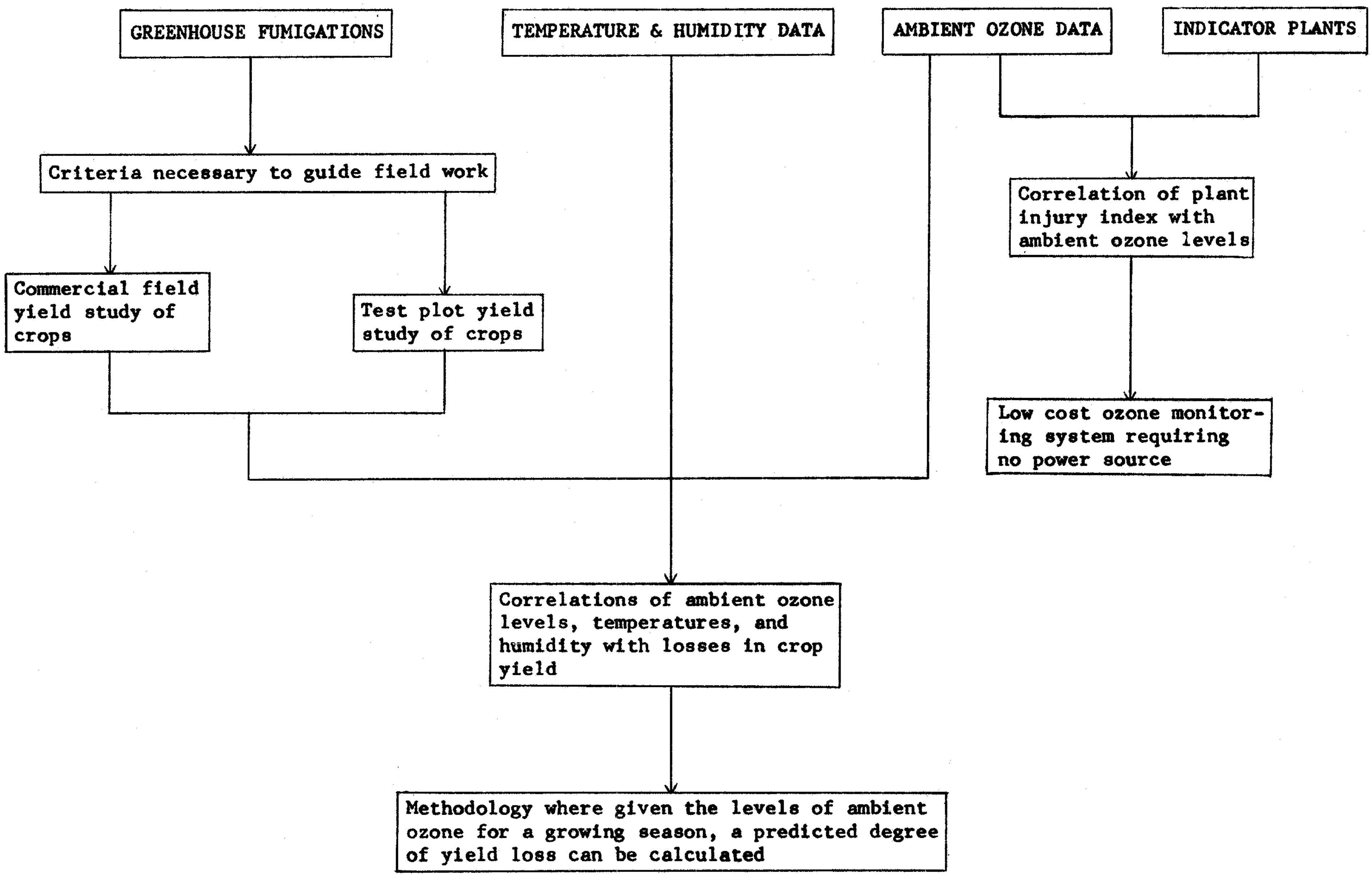
VI. Valencia Oranges on Troyer

105	Orange Co.
106	" "
109	" "
120	Riverside Co.
125	" "
133	San Bernardino Co.
134	" " "
139	Ventura Co.
140	" "
143	" "

VII. Tioga Strawberries

601-609	U.C.R. Test Plot
616-624	S.C.F. Test Plot

Figure 1. OUTLINE OF THE COMPONENT FUNCTIONS AND ASSOCIATIONS OF THE AIR POLLUTION METHODOLOGY PROGRAM



OZONE DOSAGE-CROP LOSS CONVERSION FUNCTION

A demonstration prototype ozone dosage-crop loss conversion function was constructed from the 1973 program's sweet corn data (Table 4) to illustrate the potential of an operational function. Given the seasonal ozone dosage, probability that the mean ear weight of Golden Jubilee corn ears would be below the 315 gm reference threshold could be predicted. The conversion function predicts the probabilities over a range of given dosages. The associated characteristic could be changed to include a predicted number of ears below the reference threshold or the percentage of such ears in a given field. This prototype is not an operational conversion function as major variables such as soil type, cultural practices, and fertilization have not been tested. It does, however, demonstrate the type of assessment methodology which will soon be available. Viable operational conversion functions are being developed for sweet corn and alfalfa in the 1974-75 program and will be presented in its final report.

Developmental Procedures

Fourteen yield plots representing eight geographical areas were established and harvested during the 1973 yield study. The mean unhusked ear weights characteristic of each area were correlated via a multiple regression correlation with the monitored variables of ozone dosage, average daily relative humidity for the season, average seasonal maximum temperature, and average seasonal minimum temperature for each area's growing season to determine significance (Table 5). Seasonal ozone dosages were significantly correlated with mean unhusked ear weights in the regression correlation and ozone dosage t-values calculated during the multiple regression correlation were responsible for most significant interactions. The other measured variables were found to be insignificant. Two interactions were found to be significant and did not include dosage. The overwhelming evidence that ozone dosage was the primary influence affecting unhusked ear weight reductions was clear. It should be stipulated, however, that many variables which may have influenced these results remained uncontrolled during this program and the results should not be construed as the total picture. The 1974-75 program should clarify results as it will standardize many variables that were uncontrolled in this program.

A linear and hyperbolic correlation were tested to delineate the correct functional relationship between ozone dosage and reductions in unhusked ear weights using the 14 yield plots (Figure 1). Unfortunately, both correlations were significant at the .01 level and several points must be added in the 1000 to 3000 ozone dosage range to determine the correct functional relationship (Table 6). This has been included in the 1974 program.

A demonstration prototype ozone dosage-crop loss function was calculated using the linear regression. However, its development could be altered to conform to a curvilinear function as well. A reference threshold of 315 gms unhusked corn ear weight was incorporated to determine marketability, but, this value is an arbitrary one and could be changed. T-values were calculated at specific dosages using the following formulas where:

x_i = oxidant dose (independent variable) for the ith observation

y_i = value of characteristic (dependent variable) for the ith observation

$\bar{x}$ = mean of observed dosages

$\bar{y}$ = mean of observed characteristic values

n = number of observations

$\hat{y}$ = predicted value of characteristic according to linear regression equation

x = any oxidant dosage at which one wants to calculate $\hat{y}$ or t

Equation 1. $\hat{y} = mx + b$ (linear regression equation)

Equation 2.

$$m = \frac{\left[\sum\left(x_i y_i\right)^2 - \frac{\left(\sum x_i y_i\right)^2}{n}\right]}{\left[\sum x_i^2 - \frac{\left(\sum x_i\right)^2}{n}\right]} = \text{slope or coefficient of regression line}$$

Equation 3. $\hat{y} = m\,(x-\bar{x}) + \bar{y} = mx + b$

$b = \bar{y} - m\bar{x}$ = intercept of regression line

<u>For any characteristic value y^1 such as y^1 = 315 gms</u>

Equation 4. $y^1 = \hat{y} \quad tS_{\hat{y}}$ predicted $y \pm t$ x error

Equation 5.

$$S_{\hat{y}} = \sqrt{S^2_{y.x}\left[1 + \frac{1}{n} + \frac{\left(x - \bar{x}\right)^2}{\sum\left(x_i - \bar{x}\right)^2}\right]} = \text{estimated standard error of } y$$

Equation 6.

$$S^2_{y.x} = \frac{\sum\left(y_i - y_i\right)^2}{n-2} = \text{mean square deviation from regression}$$

Substituting into equation 4. and solving for t at some x

$315 = mx + b \pm tS_{\hat{y}}$

Equation 7.

$$t = \pm\left[\frac{315 - mx - b}{S_{\hat{y}}}\right]$$

Similarly one can calculate t-values for a multiple regression equation

$\hat{y} = m_1\, x_1 + m_2\, x_2 + m_3\, x_3 \ldots\ldots\ldots tb$

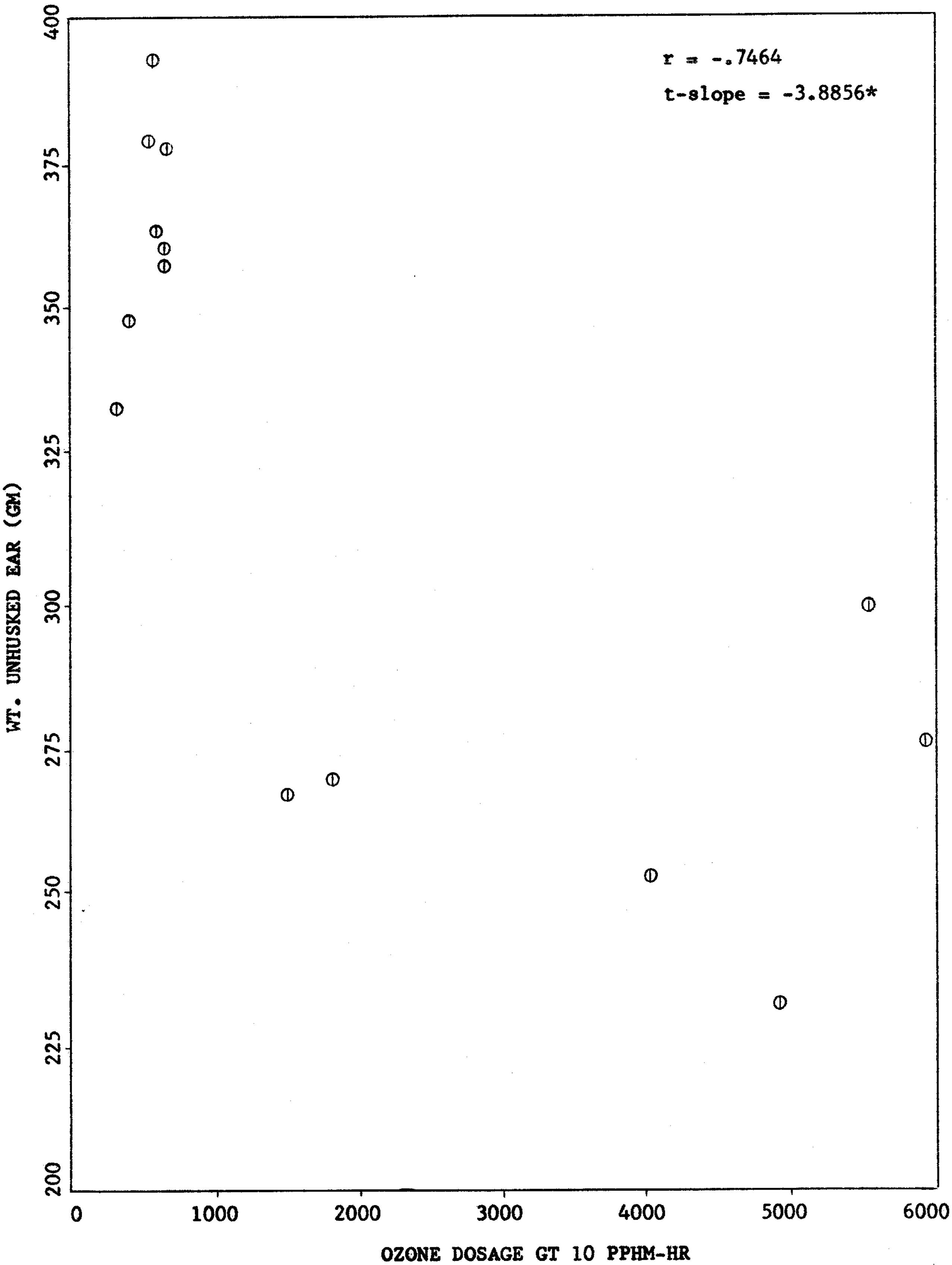
where x_1, x_2, x_3.........are independent variables

and m_1, m_2, m_3...........are their coefficients

Calculated t-values are converted to predicted probabilities by means of a t-table. Each dosage is given its corresponding probability range.

Pollution dosage-crop loss conversion functions will allow translation of ambient seasonal dosages in areas to predicted losses. Losses would be represented by whatever crop characteristic the marketing criteria deems to be limiting and are therefore easily convertible into economic terms. All conversion functions would be developed from field data representative of the environmental conditions present in a geographical region. Climatological extremes are thus tested for significant influences on crop yields. Conversion functions would therefore be viable for environmental variables characterizing a region and could be tested for areas where environmental conditions extend beyond those of the referenced region.

Figure 2. Linear regression correlation of 1973 seasonal ozone dosages and mean weights of harvested corn ears.



*Significant at .01

Table 4. Calculated probabilities in percent that the mean weight of Golden Jubilee corn ears will be below a 315 gm reference threshold. Calculations are based on a linear relationship between seasonal ozone dosage and ear weight reduction.

DOSAGE	CALC. T	PROBABILITY	DOSAGE	CALC. T	PROBABILITY
0	-1.216	10-20	3750	0.591	70-75
250	-0.954	10-20	4000	0.801	75-80
500	-0.723	20-30	4250	1.043	80-90
750	-0.524	30-40	4500	1.316	80-90
1000	-0.356	30-40	4750	1.621	90-95
1250	-0.22	40-50	5000	1.958	95-97.5
1500	-0.115	40-50	5250	2.326	97.5-98.75
1750	-0.042	40-50	5500	2.725	98.75-99.5
2000	-0.0	40-50	5750	3.156	99.5-99.75
2250	-0.01	40-50	6000	3.619	99.75-99.9
2500	0.011	50-60	6250	4.113	99.9-99.95
2750	0.064	50-60	6500	4.638	>99.95
3000	0.149	50-60	6750	5.195	>99.95
3250	0.264	60-70	7000	5.784	>99.95
3500	0.412	60-70			

Table 5. Summary of results from the regression correlations with field average unhusked ear weights from Golden Jubilee corn, ozone dosage, average seasonal maximum temperature, average seasonal minimum temperature and average daily relative humidity for a season.

Linear Correlations	Correlation Coefficients
un wt vs. dose	- .7672*
un wt vs. T max	- .6330
un wt vs. T min	- .1488
un wt vs. RH	.5525

Regression Matrix	T-values of Regression Coefficient			f-values
	dose	character	character	
un wt vs. dose & T max				3.6178
un wt vs. dose & T min				5.744
un wt vs. dose & RH	-3.2495*	2.0530		8.6989*
un wt vs. T max & T min		-3.5133*	2.3726	6.3682*
un wt vs. T max & RH		-3.0119*	2.6719*	7.6282*
un wt vs. T min & RH				4.8025
un wt vs. dose & T max & T min				4.5314
un wt vs. dose & T max & RH				5.1551
un wt vs. dose & T min & RH				4.7270
un wt vs. T max & T min & RH				4.2266
un wt vs. dose & T max & T min & RH				3.0027

* Denotes significance at the .05 level.

Table 6. Linear and hyperbolic correlations of unhusked ear wts. and seasonal ozone dosage.

<u>Linear correlation between unhusked ear wts. and seasonal ozone dosage</u>

Correlation coefficient:	-0.7464	
Slope:	-0.0191	STD error of slope: 0.0049
Intercept:	360.9839	
T-slope:	-3.8856**	

<u>Hyperbolic correlation between unhusked ear wts. and seasonal ozone dosage</u>

Correlation coefficient:	0.7299	
Slope:	41417.1797	STD error of slope: 11195.1869
Intercept:	270.5315	
T-slope:	3.6995**	

** Denotes significance at the .01 level

AMBIENT OZONE AND CLIMATOLOGICAL DATA MONITORING

Instrument Ozone Data

Three general types of instruments are used to monitor ozone in the South Coast Air Basin: 1) colorimetric or coulimetric analyzers utilizing the oxidant reaction with a potassium iodide (KI) solution, 2) ethylene chemiluminescent ozone instruments, 3) ultra-violet absorption instruments. Instruments of the last two types are ozone-specific. Instruments using the colorimetric or coulimetric method monitor all oxidants which react with the KI solution.

Ozone normally comprises all but an extremely small increment of the total oxidants in the South Coast Air Basin during daylight hours. Nitrogen dioxide (NO_2) is dissipated during the synthesis of atmospheric ozone and generally does not exist in significant quantities when ozone is present. Some overlap exists in early morning or evening but the amount is usually negligible as NO_2 sensitivity is only 10% of the total oxidant scale when compared with ozone. The overlapping periods usually exhibit very low total oxidant levels.

Peroxyacetyl nitrate (PAN) does exist in conjunction with ozone during daylight hours but only at extremely low levels, approximately 0.1% of the total oxidant scale when compared to ozone.

Variability among instruments of any one model and differences in efficiency of maintenance and operation by different agencies make the calculation of equilibrating factors impossible.

All data received, whether from ozone-specific instruments or total oxidant instruments, have therefore been used as measurements of ozone and compared against each other. Hourly averages above 10 pphm, the California standard for oxidant air pollutants, were used to calculate the average weekly dosage (AMBI correlations) and total dosages (field correlations) pphm hours for the respective seasons. Only hourly averages for the daylight hours were used, as plant sensitivity to oxidants is reduced at night.

The hourly PAN levels at UCR were monitored by an Aerograph Panalyzer Model 681. PAN levels for the Anaheim-Garden Grove and Covina-Glendora areas were monitored by Aerograph Panalyzers from the EPA funded CHESS program's monitoring stations. This program cooperated by providing PAN monitoring data for correlations with Snowstorm petunia injury from AMBI stations in close proximity.

Field locations within a five-mile radius of an instrument station were assigned the ozone dosages recorded by that station. Dosages for field locations outside the radius of an instrument station were computed through interpolation. The following formula was used:

$$I = \frac{\left(\frac{O_1}{d_1} + \frac{O_2}{d_2} + \frac{O_3}{d_3}\right)}{\left(\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3}\right)}$$

where: I = interpolated dosage

O = oxidant dosage

d = distance from instrument

Instrument stations used in interpolations were selected for their proximity to the field location and their relative position in relation to the location.

Climatological Data

Daily maximum and minimum temperatures were procured from instrument stations with the South Coast Air Basin. The National Weather Service, Military bases, County Air Pollution Control Districts, and Fruit Frost Service were cooperative in supplying the necessary data.

Hourly relative humidity data was collected from the same sources. Daily averages were used to calculate the mean seasonal values at locations.

Air Monitoring Biological Indicator (AMBI) System

Three AMBI units were used to monitor each field location to insure against malfunction and to obtain an adequate number of plant injury observations. Indicator plants were changed and evaluated at regular weekly intervals.

Each AMBI station was adjusted to maintain six indicator plants. After extensive testing the following plants were selected:

3 Pinto beans (Variety U.I. 111 Lot D415 Burpee Seed Company)
1 Snowstorm petunia (Burpee Seed Company)
2 California Mariot barley (UCR source)

The pinto beans were used as ozone indicators, the petunias as the PAN indicator, and barley as a check for both ozone and PAN injury.

Care was taken to preserve as much uniformity as possible in the growth and selection of each variety of indicator plant. Plants were potted in four-inch pots using the same standard soil mix utilized in the quality study.

Ingredients/cubic yard of soil

1. 1/3 loam, peat moss, redwood
2. 4 oz. KNO_3
3. 4 oz. K_2SO_4
4. 2 lbs. single super phosphate
5. 4 lbs. $CaCO_3$
6. 5 lbs. Dolomark lime
7. 1 lb. 10 oz. Isobutylidene diurea (IBDU)

All plants were used at standard ages relative to their sensitivity. Pinto beans were set out 10-12 days old (2 primary leaves), petunias 20-25 days old (6-7 leaves), and barley 16-19 days old (3-leaf stage).

An air conditioned 1973 1/2 ton GMC van was modified and used as the transportation vehicle. The load area was insulated and fitted with an activated charcoal filter to remove oxidants. A regular weekly schedule for indicator plant replacement and AMBI station maintenance proved to be effective. A route servicing a different sector of the air basin was followed each day.

The photo-reference plant evaluation system described in the 1972 quality study was used as the plant injury evaluation system. The same five injury rating classification from the 1972 report were used for pinto beans and petunias. Calculations were made with the following formulas:

1)

$$Aj = \frac{\sum_{i=1}^{nj} Iij}{nj} = \text{weekly average injury for week j}$$

2)

$$Am = \frac{\sum_{j=1}^{m} Aj}{m} = \text{average weekly injury for m weeks}$$

where: Iij = injury of ith plant during jth week
nj = number of plants during jth week
m = number of weeks

The evaluated ozone injury for each plant was averaged for each week of the season. The averages were then summed and divided by the number of weeks to yield the average weekly injury per plant, per season.

The limited number of PAN monitoring equipment necessitated trying dosage injury correlations on a monthly basis. The plant injury-PAN dosage values for each month at each location were plotted. Values were calculated from the same injury formulas used for ozone injury on Pinto beans with the exception that the average weekly injury values for four weeks were summed, then divided by 4 to produce the monthly values.

Correlation of Plant Injury with Ambient Ozone and PAN Dosages

Ozone injury-dosage correlations from AMBI station monitoring data were found to be significant at .025 level of significance (Figures 3, 4, 5) for the spring and summer growing seasons of 1973. The following key identifies locations used in the correlations:

1. Rubidoux
2. Hemet
3. Azusa
4. UCR
5. Corona
6. Irvine (SCFS)
7. Anaheim-Costa Mesa
8. Redlands
9. Anaheim
10. Anaheim-Corona-LaHabra
11. Chino
12. Costa Mesa

Climatological variables tested in the multiple regression were found to be significant except in interactions with dosage. However, the t-values used in the regression calculations show dosage to be responsible for these significant interactions (Table 7). Average seasonal minimum temperatures, average seasonal maximum temperatures and average seasonal daily relative humidity were not significant.

PAN monthly dosages were correlated with Snowstorm petunia injury and the same three climatological variables used in the ozone dosage-injury regression. PAN dosage proved to be the only significant variable tested with no significant interactions.

This replicate year of testing showed the AMBI system of indicator plants to be a reliable method of monitoring pollutant levels for agricultural regions. Its low cost, mobility, and ease of maintenance would make it ideal for seasonal monitoring in rural regions until instrument stations were established.

Table 7. Summary of significant results from regression correlations with leaf injury evaluations, pollutant dosages, average seasonal minimum temperature, average seasonal maximum temperature, and average seasonal daily relative humidity.

I. Spring Ozone Dosage - Pinto Bean Injury Regression

Regression Matrix	T-values of Regression Coefficient		f values
	dose	character	
injury vs. dose			8.51*
injury vs. dose & T min.	2.91*	1.07	4.91*
injury vs. dose & T max.	3.23*	-1.27	5.36*
injury vs. dose & RH	2.47*	0.92	4.61*

II. Fall Ozone Dosage - Pinto Bean Injury Regression

Regression Matrix	T-values of Regression Coefficient		f values
	dose	character	
injury vs. dose			9.54*
injury vs. dose & T min.	3.22*	1.18	5.70*
injury vs. dose & T max.	2.95*	-0.73	4.76

III. PAN Dosage - Petunia Injury Regression

Regression Matrix	f values
injury vs. dose	5.79*

Figure 3. Correlation of average weekly oxidant doses for autumn 1973 with the average weekly pinto bean injury index at field locations in the South Coast Air Basin. A confidence level of 95% is associated with this correlation.

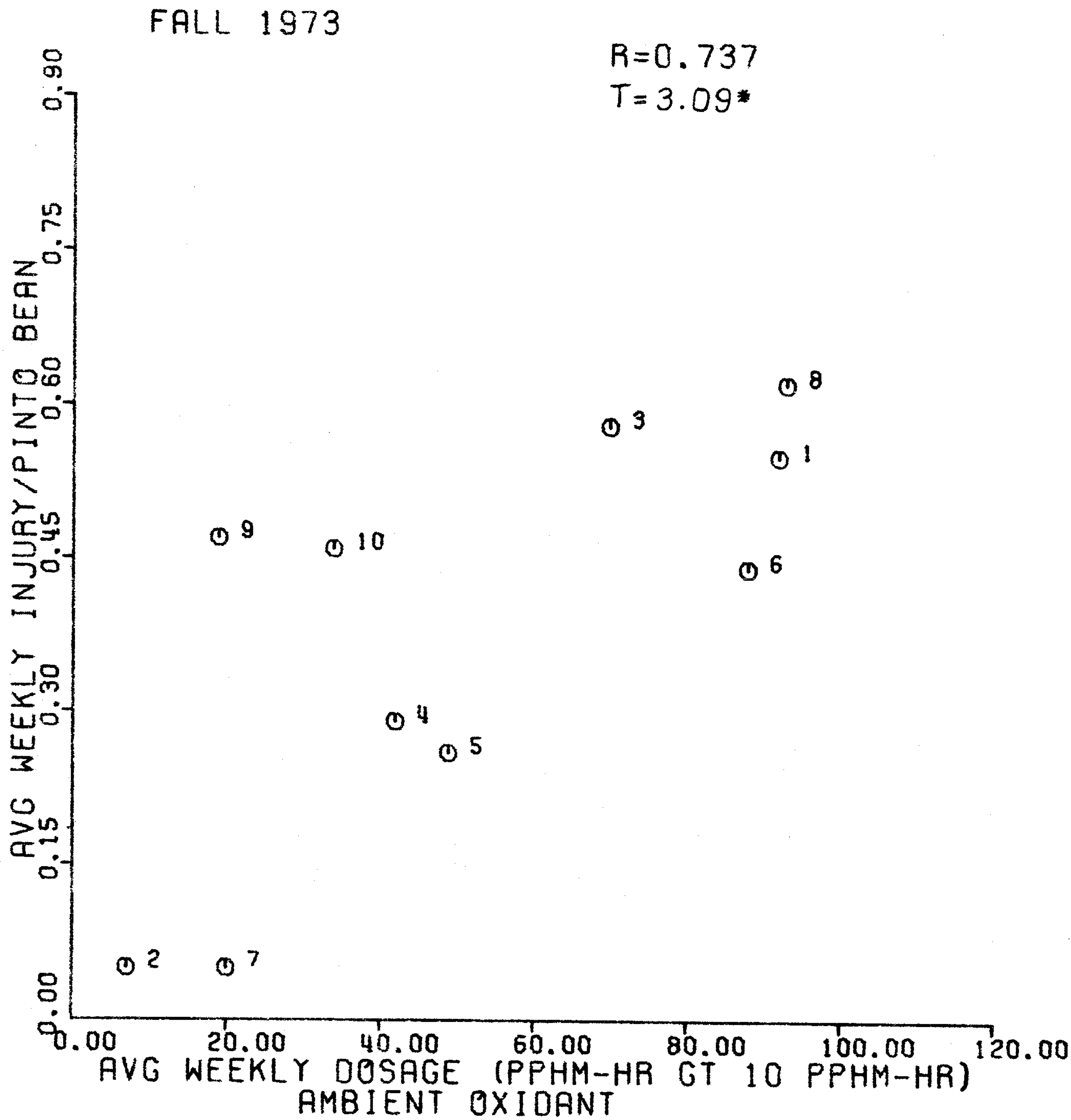


Figure 4. Correlation of average weekly oxidant doses for spring 1973 with the average weekly pinto bean injury index at field locations in the South Coast Air Basin. A confidence level of 95% is associated with this correlation.

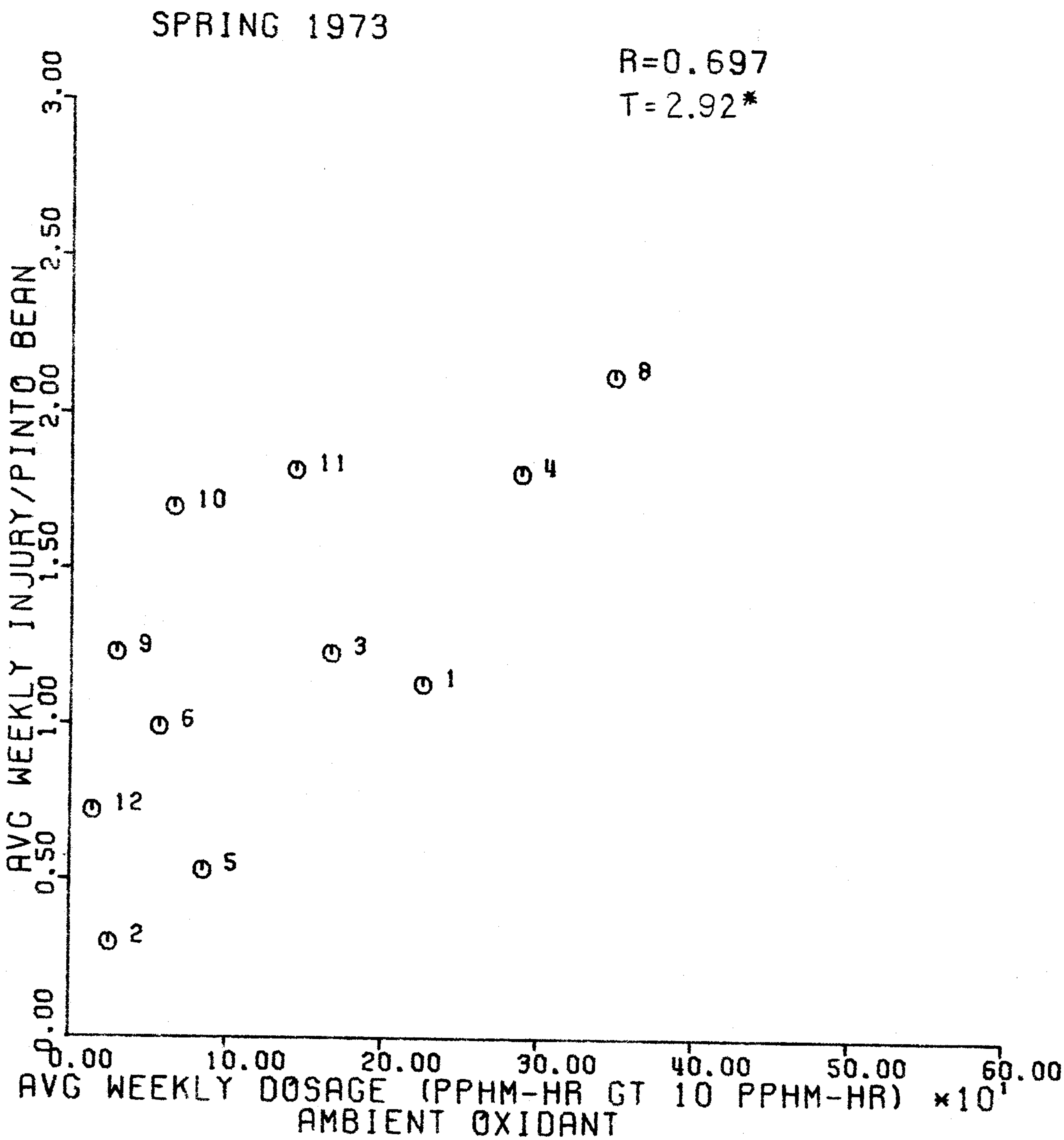
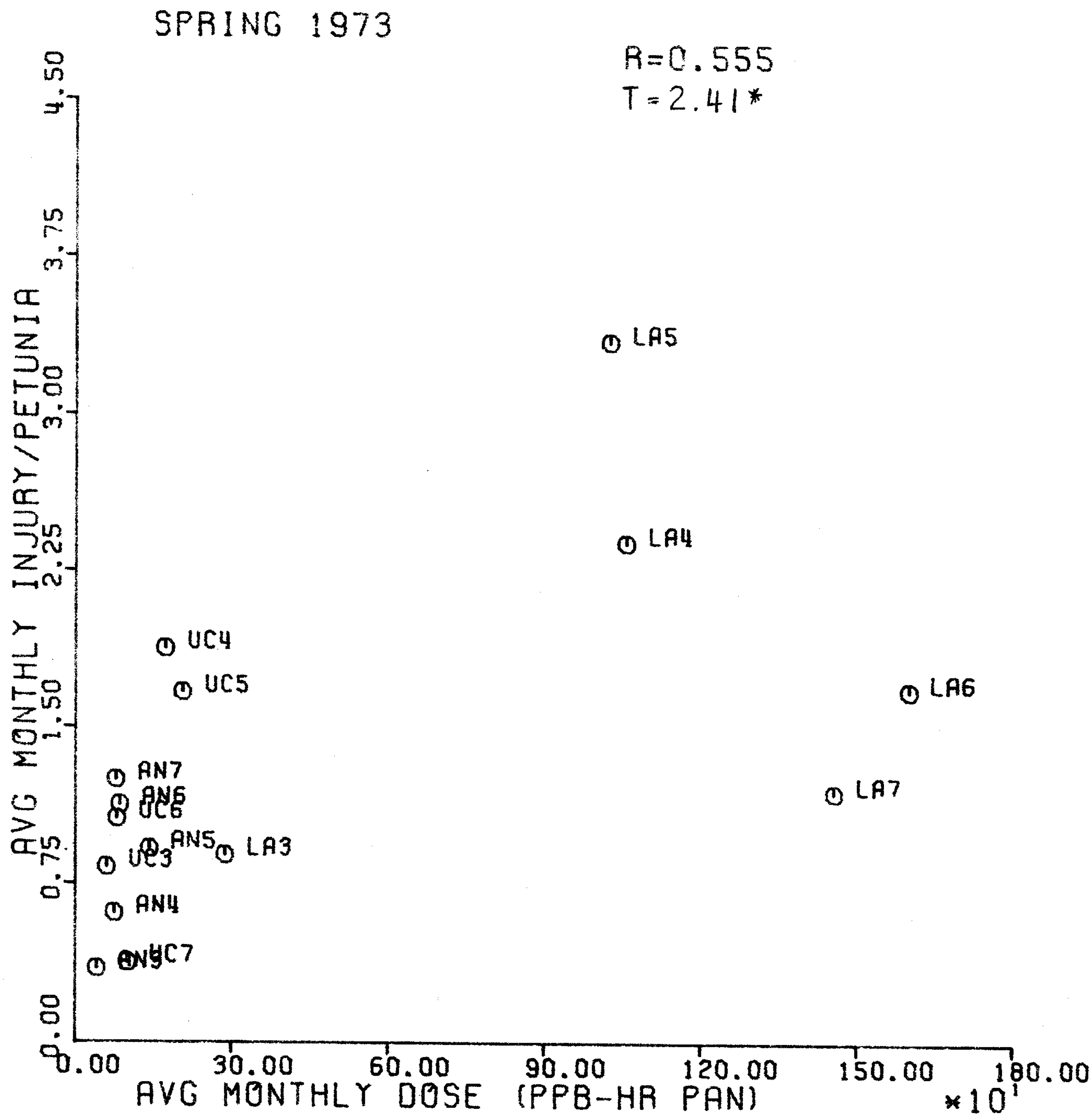


Figure 5. Correlation of weekly average peroxyacetyl nitrate (PAN) doses for spring 1973 at U. C. Riverside, Anaheim-Garden Grove (AN) and Covina-Glendora (LA) with the weekly average petunia injury index. A confidence level of 95% is associated with this correlation.



CORN

Introduction

Golden Jubilee sweet corn was utilized for the yield phase of this program because of its distribution and popularity throughout the South Coast Air Basin and was also selected as the test crop for the prototype ozone dosage-crop loss conversion function development.

Long-Term Ozone Fumigation

Treatments: 0 ppm ozone, .25 ppm ozone, .30 ppm ozone

Exposure: Treatments were exposed to their respective concentrations of fumigant 85 out of a total 1400 hours or about 5.8% of the growing period. Fumigations were about six hours in duration and at a frequency of 1.5 times a week.

Results: Long-term ozone fumigation results differed dramatically from the 1972 fumigations. No significant differences in stature were found among treatment plants but variations in the dry weights of the plants were observed (Table 8). The yields as measured in unhusked weights of ears did not vary significantly among treatments.

Discussion: It appeared that the frequency of exposures was a much more critical loss parameter than exposure duration. Exposure levels were well within the range causing foliar injury and typical ozone damage was observed on leaves in both fumigated treatments. The recovery period between exposures varied considerably between the 1972 and 1973 experiments and apparently altered results to a large degree. The fumigation schedule for the 1973 fumigations allowed alternating 3 and 4 day intervals between exposures at a given concentration (Table 9). The 1972 fumigation schedule only allowed single day recovery periods during the week and a maximum of two days during weekends. Although the amount of total exposure and length of exposures were greater in the 1973 study, the effects of the long-term fumigations did not approach the effects of the 1972 fumigations. These results infer that frequency of exposure played the most critical role in determining yield reductions. A thorough study of the effect of exposure frequency and duration should be undertaken as they relate to plant injury and yield reductions.

Nutritional Analyses of 1972 Fumigation Studies (7)

All analyses were run with standard procedures utilized by the Western Regional Laboratory, United States Department of Agriculture, Berkeley, California.

I. PAN Fumigated Golden Jubilee Sweet Corn Ears

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Results: A reduction in proteins and nitrogen was found in the ears from the high concentration treatment plants (Table 10). The only other significant change was an increase in the lead content of fumigated ears. Actual lead concentrations per 100 gms fresh weight of sample were as follows: (control) .10 mg, (20 ppb) .32 mg, (40 ppb) .38 mg.

II. Ozone Fumigated Golden Jubilee Sweet Corn Ears

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Results: Fumigated ears were found to contain significant reductions in the levels of solids, carbohydrates, vitamin A, and calories when compared to control ears (Table 11). However, proteins, vitamin C, and the levels of several of the metals were found to be higher in fumigated treatment ears. Exposed ears were significantly lower in fresh ear weights when measured and also appear to have less storage materials. The increase in the protein and vitamin C levels could possibly be due to an injury mechanism but cannot be explained at this time.

Field Study

The large number of commercial sweet corn growers planting Golden Jubilee and the distribution of fields over the South Coast Air Basin provided the best range of ambient ozone dosages of all test crop field locations. In addition, the response to ambient ozone dosages was the best defined. Golden Jubilee sweet corn was therefore selected as the test crop for the ozone dosage-crop loss conversion development.

Locations: Six commercial field plots and two test plots of Golden Jubilee sweet corn were harvested (Map 5).

Sampling Techniques: Four 15-plant replicates were staked out at each commercial location at emergence. All primary and secondary ears were harvested and evaluated 21 days after silking. Only the primary ears were utilized in correlations but data of the number and quality of secondary ears was also taken.

Results: A significant correlation of the mean unhusked ear weights and total ozone dosages at field locations was significant at the .01 level and the husked ear weights and total ozone dosages at the .05 level (Figures 6, 7). The correlations clearly indicated an association between reduced ear weight and seasonal ozone dosage. Ears produced in the moderate to high pollution areas were 26-27% smaller than the low pollution ears as measured by unhusked ear weight. The characteristic lower vigor with increasing ozone dosage appeared to be significant when measured as the extent of blemish occurring on ears and the number of sucker shoots produced (Figures 8, 9). Significant correlations with ozone dosage and reductions in internode lengths and ear diameters were also present (Figures 10, 11). All other correlations with dosages were not significant (Figures 12 - 17).

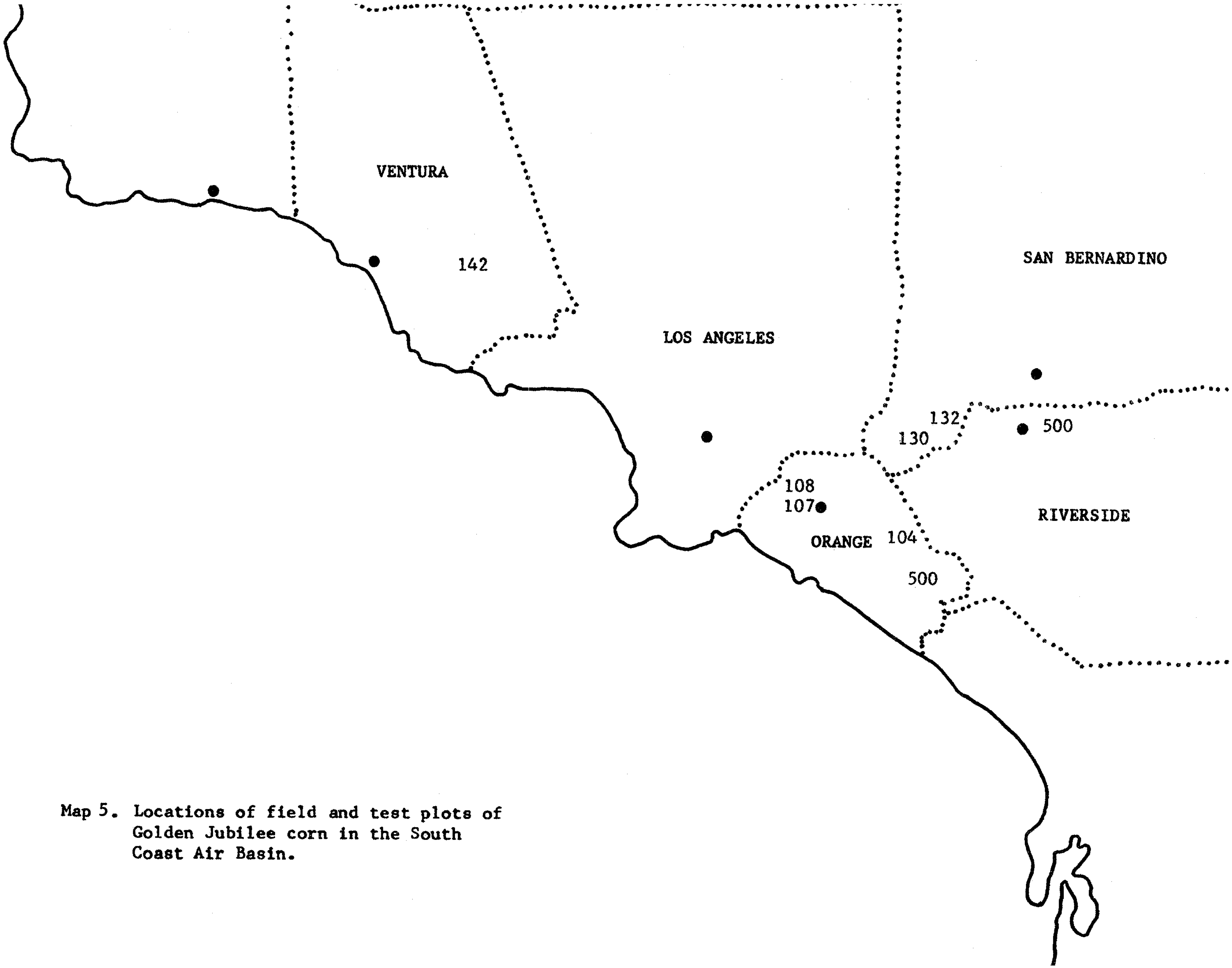
Discussion

Long-term fumigations indicated that the frequency of exposure to ozone is more critical to yield reductions than total dosage. Logically, frequent fumigations more closely approximates ambient conditions where plants are exposed to ozone over long periods of time and not on a once or twice a week basis.

Field studies confirm a significant correlation between ozone dosage and reductions in ear weight. Other measured characteristics also indicate an overall effect on the plants but are not as definitive as ear weight. The extent of blemishes on ears was within a 2 cm range and may well be associated with earworm control programs. The reduction in the number of sucker shoots present could also be due in part to differences in seed spacing at planting or fertilization. These parameters were significant in their correlation with ozone dosage but were not controlled sufficiently to be truly definitive. The controlled conditions present in the 1974 study should define the ozone effects to a much greater extent.

Ozone appears to have a marked effect on the nutritional levels of fumigated ears. The exposed ears were smaller and contained less carbohydrate and solids than ears from control plants. Vitamin levels fluctuated from those of the control ears and protein levels were increased. The overall effect may be one of nutritional reduction with certain metabolic injury reactions causing higher enzyme levels (proteins).

Golden Jubilee sweet corn was chosen as the test crop for the dosage-loss conversion function. Further data regarding its development is presented in the Ozone Dosage-Crop Loss Conversion Function chapter.



Map 5. Locations of field and test plots of Golden Jubilee corn in the South Coast Air Basin.

Table 8. Summary of significant ozone effects on Golden Jubilee sweet corn as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

Ozone Treatments (ppm)	Plant Height	No. of Nodes	Length Internodes	Plant Total Fresh Wt.
0	- a[1]	- a	- a	- a
.25	- a	- a	- a	- a
.30	- a	- a	- a	- a

Ozone Treatments (ppm)	Plant Total Dry Wt.	Fresh Wt. Husks & Stalks	Dry Wt. Leaves, Husks & Stalks	Dry Wt. Roots
0	- a A[2]	- a	- a A	- a A
.25	0.85 a A	- a	-5.3[3] a A	4.0 a A
.30	20.8 b B	- a	17.4 a A	34.22 b B

Ozone Treatments (ppm)	Ear Length	Ear Diameter	Unhusked Wt. of Ear	Husked Wt. of Ear	Dry Wt. of Ear	Blanking[4]
0	- a	- a	- a	- a	- a	2.3 a A
.25	- a	- a	- a	- a	- a	3.7 ab A
.30	- a	- a	- a	- a	- a	5.5 b A

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction represents a percent increase over the control treatment.

4. Figures given in this category represent the treatment means (cm) and not calculated percent reductions from the control treatments.

Table 9. Fumigation schedules for the 1972 and 1973 long-term ozone fumigations.

1972 Fumigations Utilizing 3-hour Exposures

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1		.20 ppm .35 ppm		.20 ppm .35 ppm		.20 ppm .35 ppm	
Week 2 thru Termination		Continuing as above					

1973 Fumigations Utilizing 6-hour Exposures

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1		.25 ppm		.30 ppm		.25 ppm	
Week 2		.30 ppm		.25 ppm		.30 ppm	
Week 3		.25 ppm		.30 ppm		.25 ppm	
Week 4 thru Termination		Continuing as above					

Table 10. Summary of the effects of PAN on nutritional constituents in Golden Jubilee sweet corn ears as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Solids			Water		Calories		Protein		
PAN	0	-	a[1]	A[2]	-	a	-	a	-	a	A
Treatments	20	-	a	A	-	a	-	a	6.82	ab	A
(ppb)	40	-	a	A	-	a	-	a	13.65	b	A

		Digestible Carbohydrates		Calculated Carbohydrates		Vitamin C Total Amino Acids		Vitamin C Reduced Amino Acids	
PAN	0	-	a	-	a	-	a	-	a
Treatments	20	-	a	-	a	-	a	-	a
(ppb)	40	-	a	-	a	-	a	-	a

		Vitamin A		Rb		Mn		Fe		Zn		K	
PAN	0	-	a	-	a	-	a	-	a	-	a	-	a
Treatments	20	-	a	-	a	-	a	-	a	-	a	-	a
(ppb)	40	-	a	-	a	-	a	-	a	-	a	-	a

		N			Pb			Cu	
PAN	0	-	a	A	-	a	A	-	a
Treatments	20	6.83	ab	A	-244.49[3]	b	B	-	a
(ppb)	40	13.65	b	A	-291.84	b	B	-	a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 11. Summary of the effects of ozone on nutritional constituents in Golden Jubilee sweet corn ears as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Solids	Water	Digestible Carbohydrates	Calculated Carbohydrates
Ozone	0	- a[1] A[2]	- a A	- a A	- a A
Treatments	.20	5.46 b B	-2.19[3] b B	3.76 a A	6.91 b B
(ppm)	.35	8.6 c B	-3.44 c B	13.18 b B	12.84 c C

		Calories	Protein	Vitamin C (Reduced Amino Acids)
Ozone	0	- a A	- a A	- a A
Treatments	.20	5.44 b B	-2.41 a A	-0.82 a A
(ppm)	.35	8.6 b B	-26.66 b B	-7.21 b A

		Vitamin C (Total Amino Acids)	Vitamin A	Rb	Fe
Ozone	0	- a A	- a A	- a A	- a A
Treatments	.20	-4.91 b A	29.01 b AB	-4.72 b B	-13.01 ab A
(ppm)	.35	-12.03 c B	28.17 b B	50.06 b B	-32.84 b A

		Zn	N	K
Ozone	0	- a A	- a A	- a
Treatments	.20	-17.3 b AB	-2.09 a A	- a
(ppm)	.35	-38.31 c B	-21.4 b B	- a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Figure 6. Correlation of unhusked weights of harvested Golden Jubilee corn ears from field and test plots with the total ambient dosage present during growth.

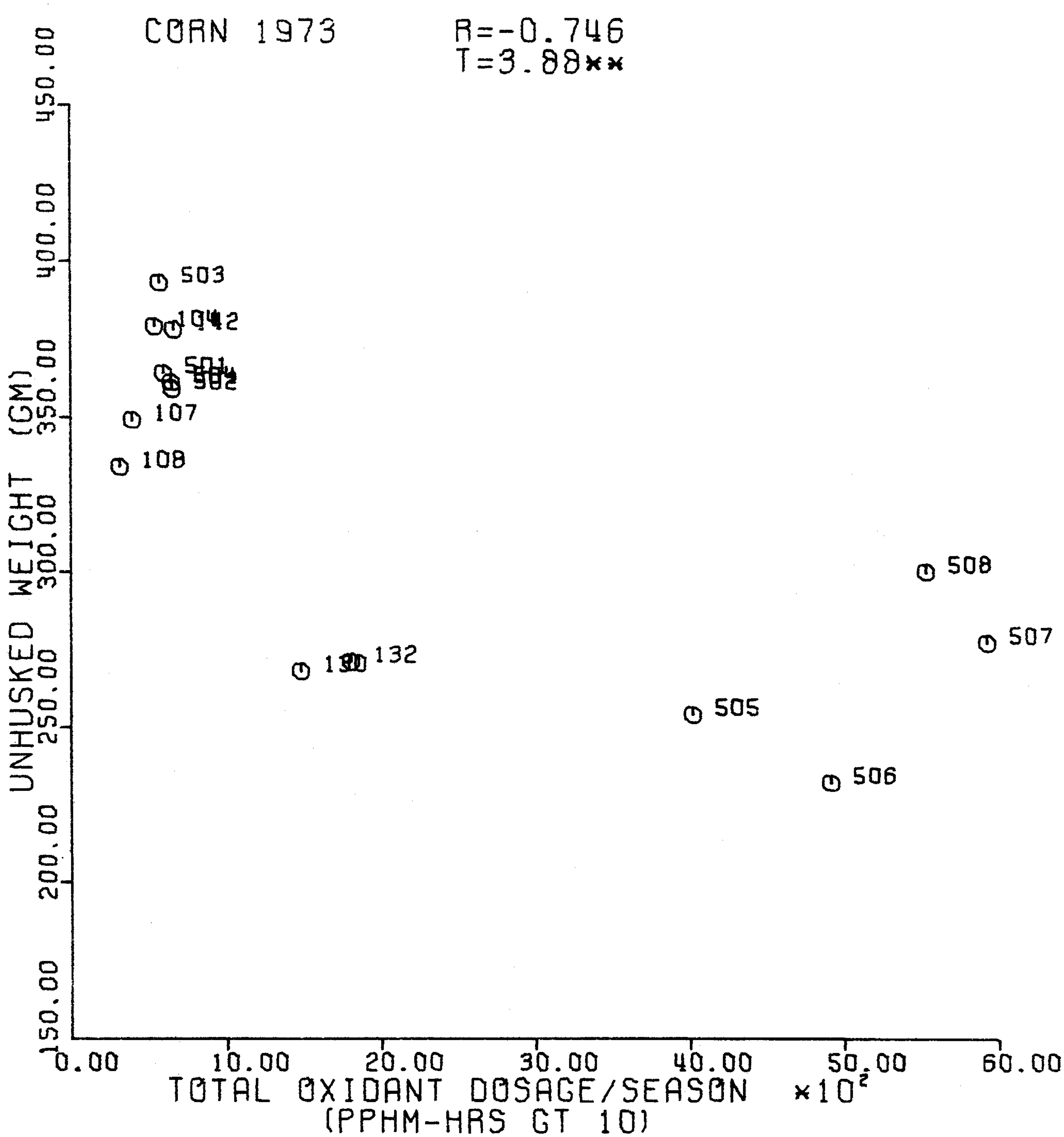


Figure 7. **Correlation of husked weights of harvested Golden Jubilee corn ears from field and test plots with the total ambient dosage present during growth.**

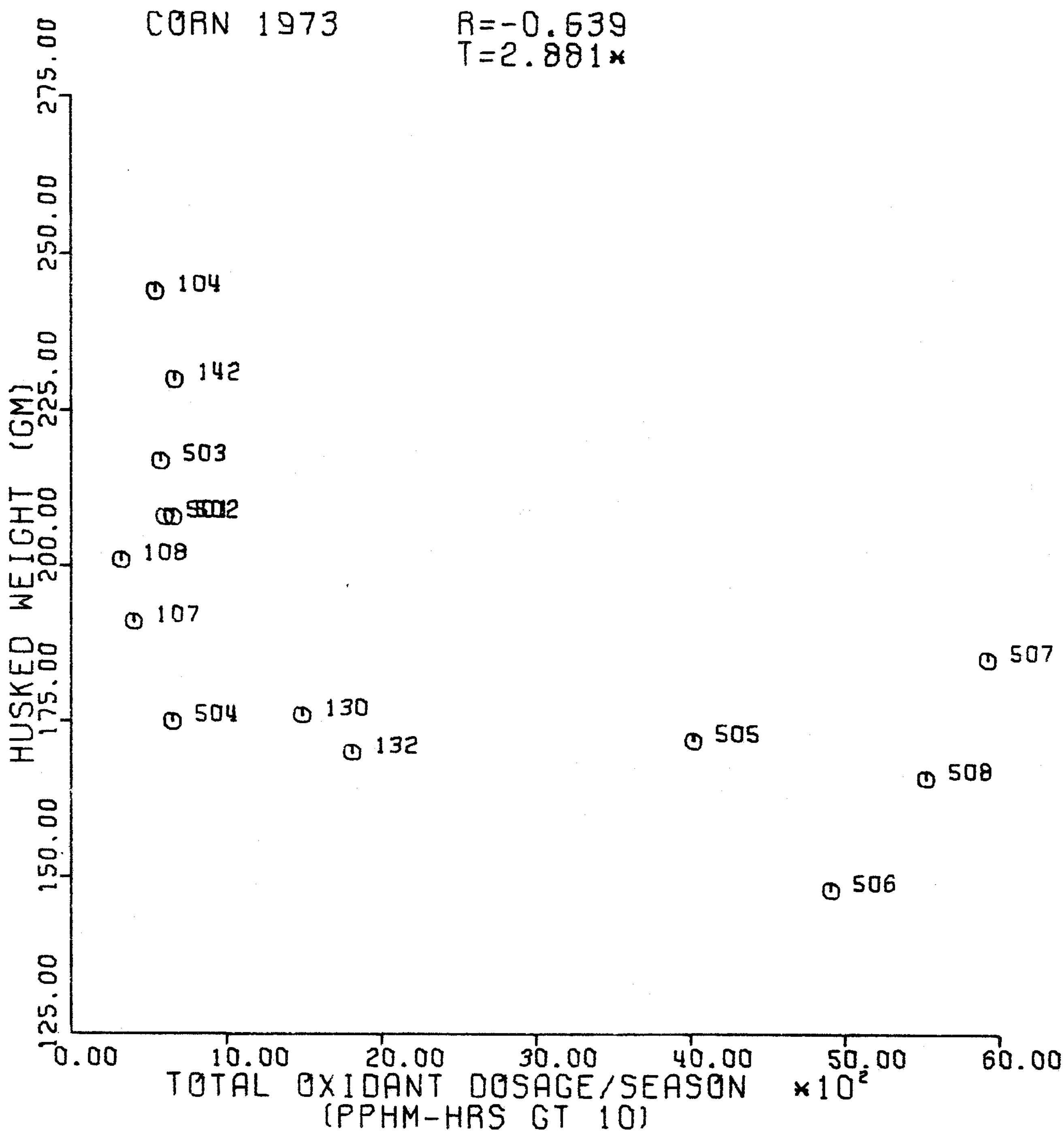


Figure 8. Correlation of the extent of blemish on harvested Golden Jubilee corn ears from field and test plots with the total ambient dosage present during growth.

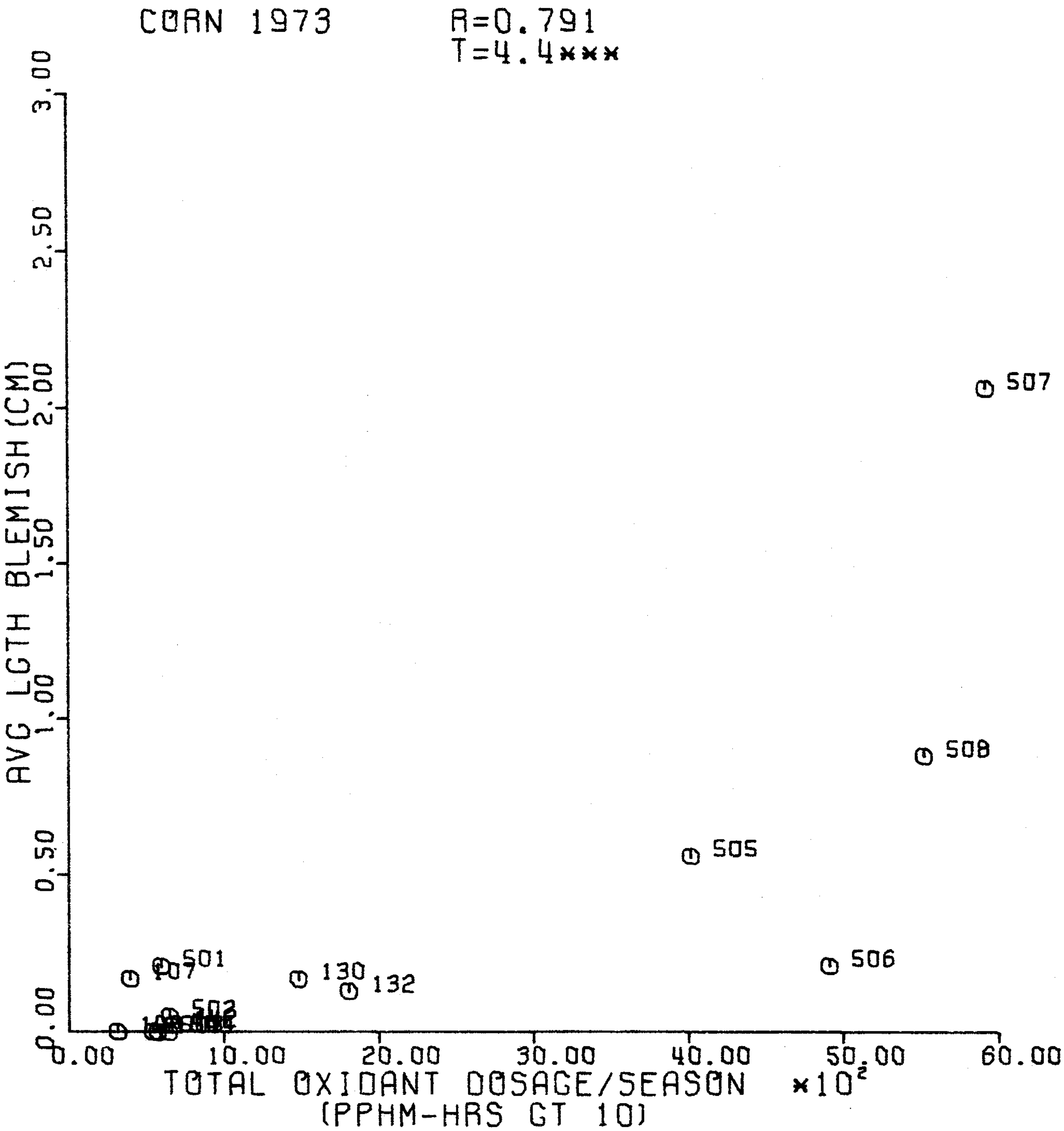


Figure 9. Correlation of the average number of suckers on field and test plot Golden Jubilee corn plants with the total ambient dosage present during growth.

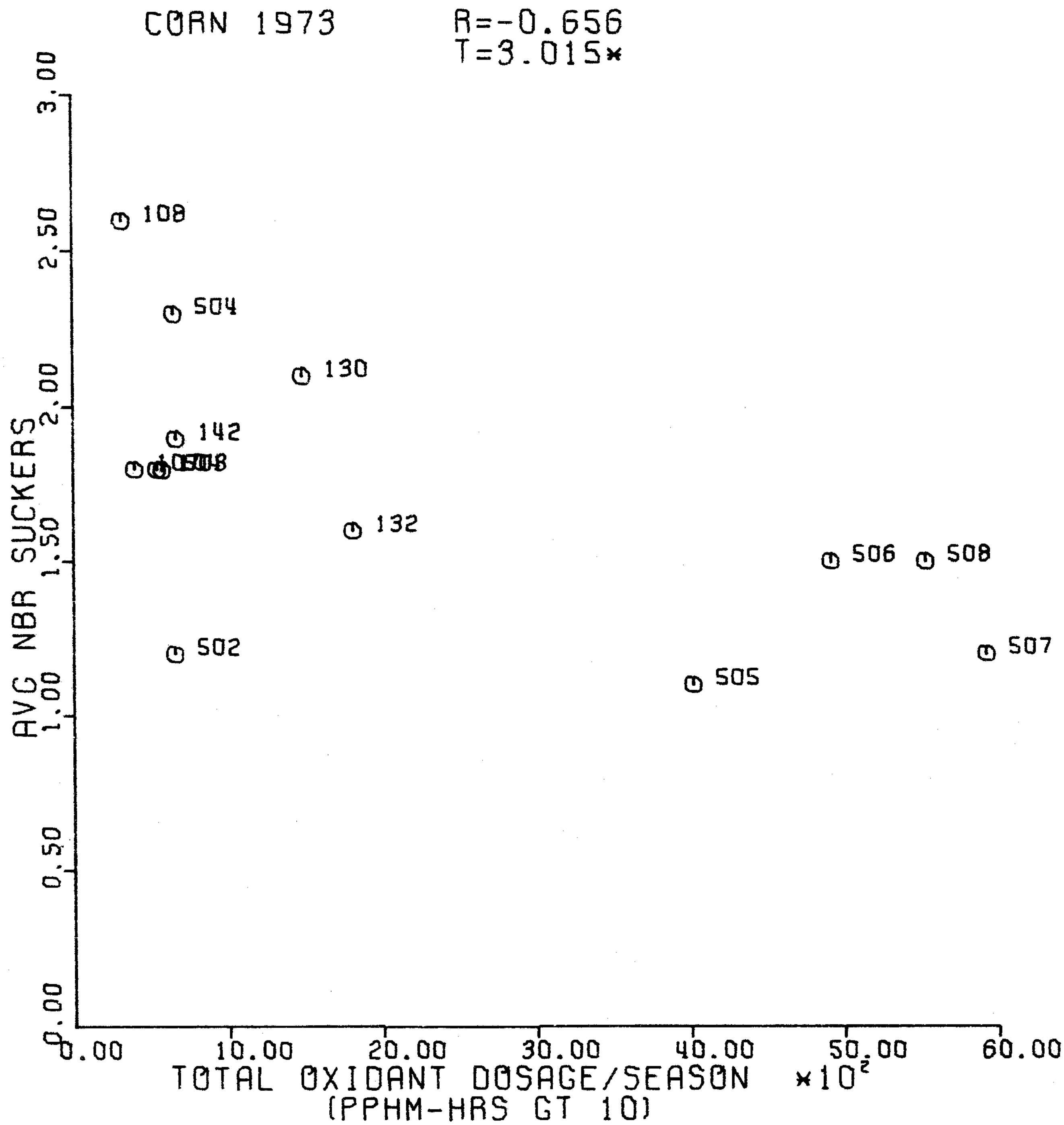


Figure 10. Correlation of the internode lengths of field and test plot Golden Jubilee plants with the total ambient dosage present during growth.

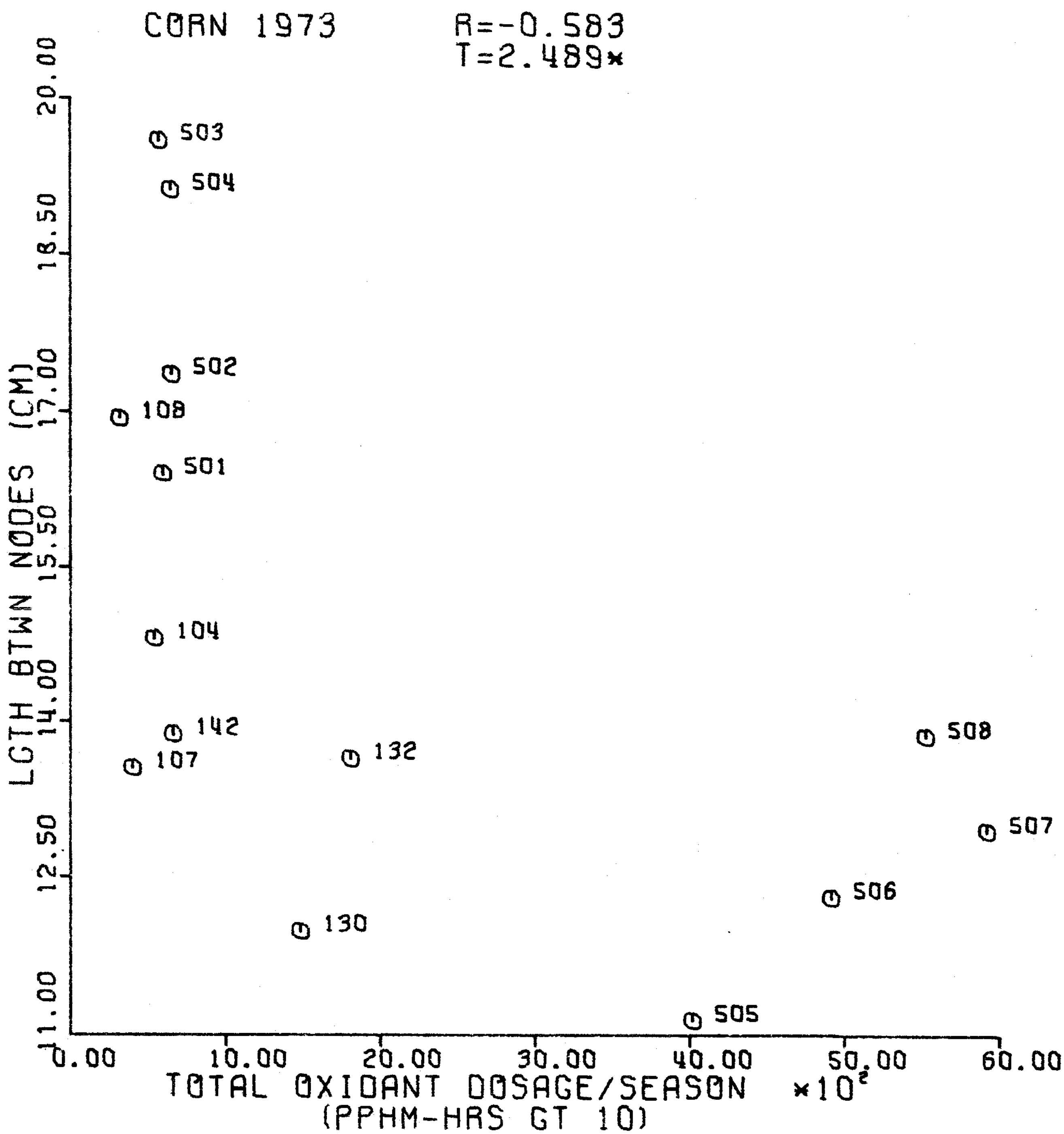


Figure 11. Correlation of diameters of harvested Golden Jubilee sweet corn ears from field and test plots with the total ambient dosage present during growth.

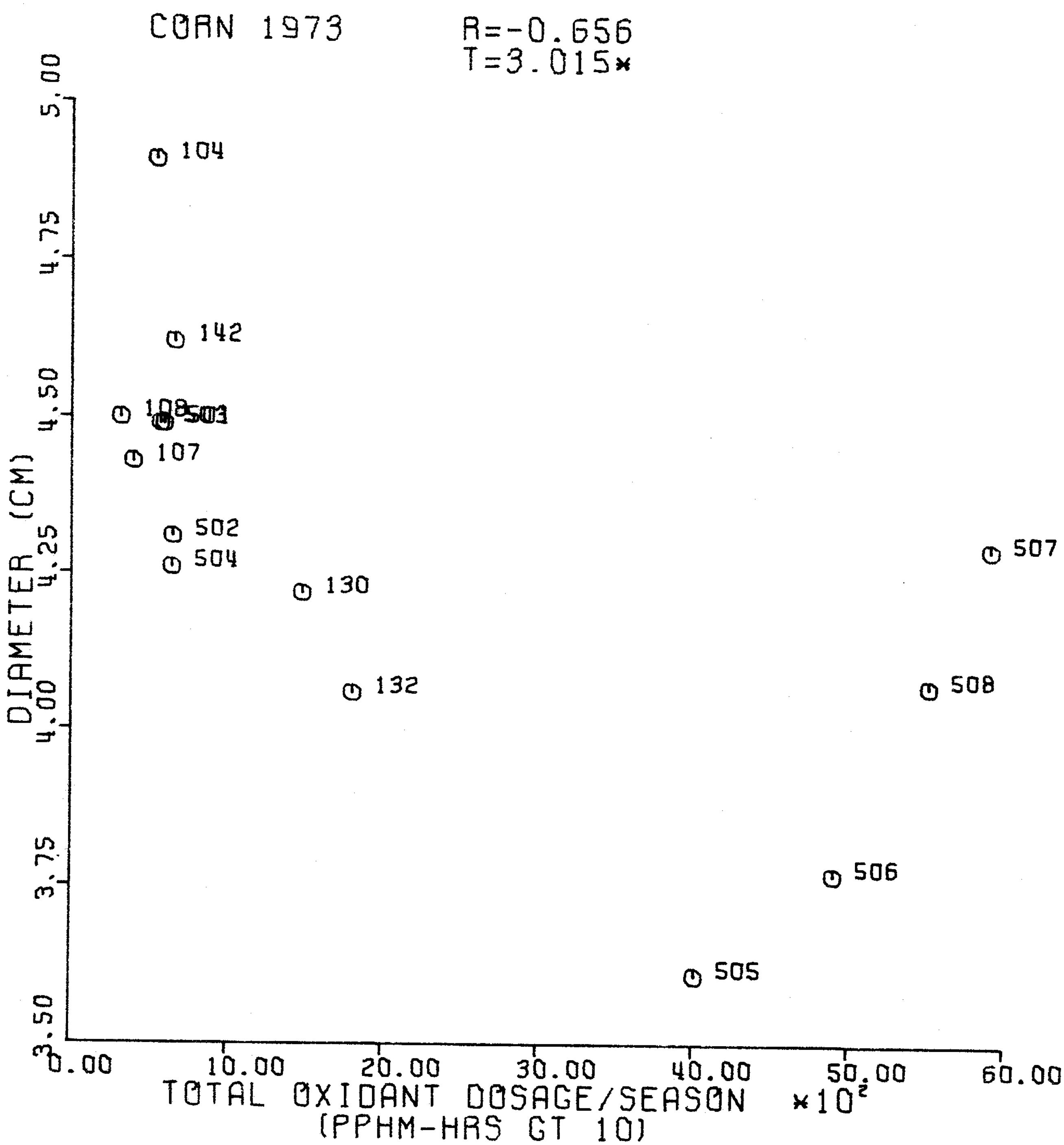


Figure 12. Correlation of the number of secondary ears from field and test plot Golden Jubilee corn with the total ambient dosage present during growth.

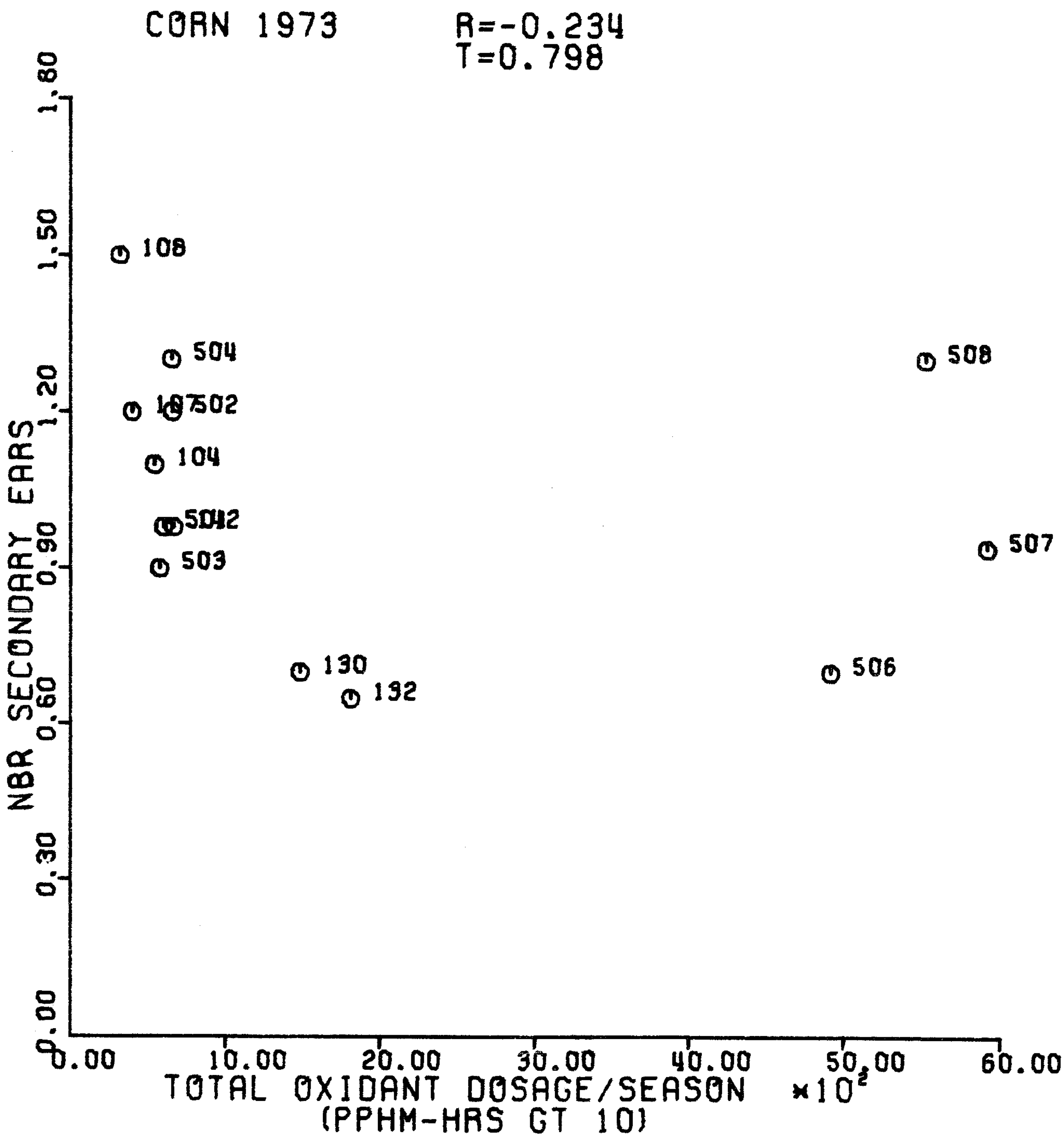


Figure 13. Correlation of the number of marketable secondary ears on field and test plot Golden Jubilee corn plants with the total ambient dosage present during growth.

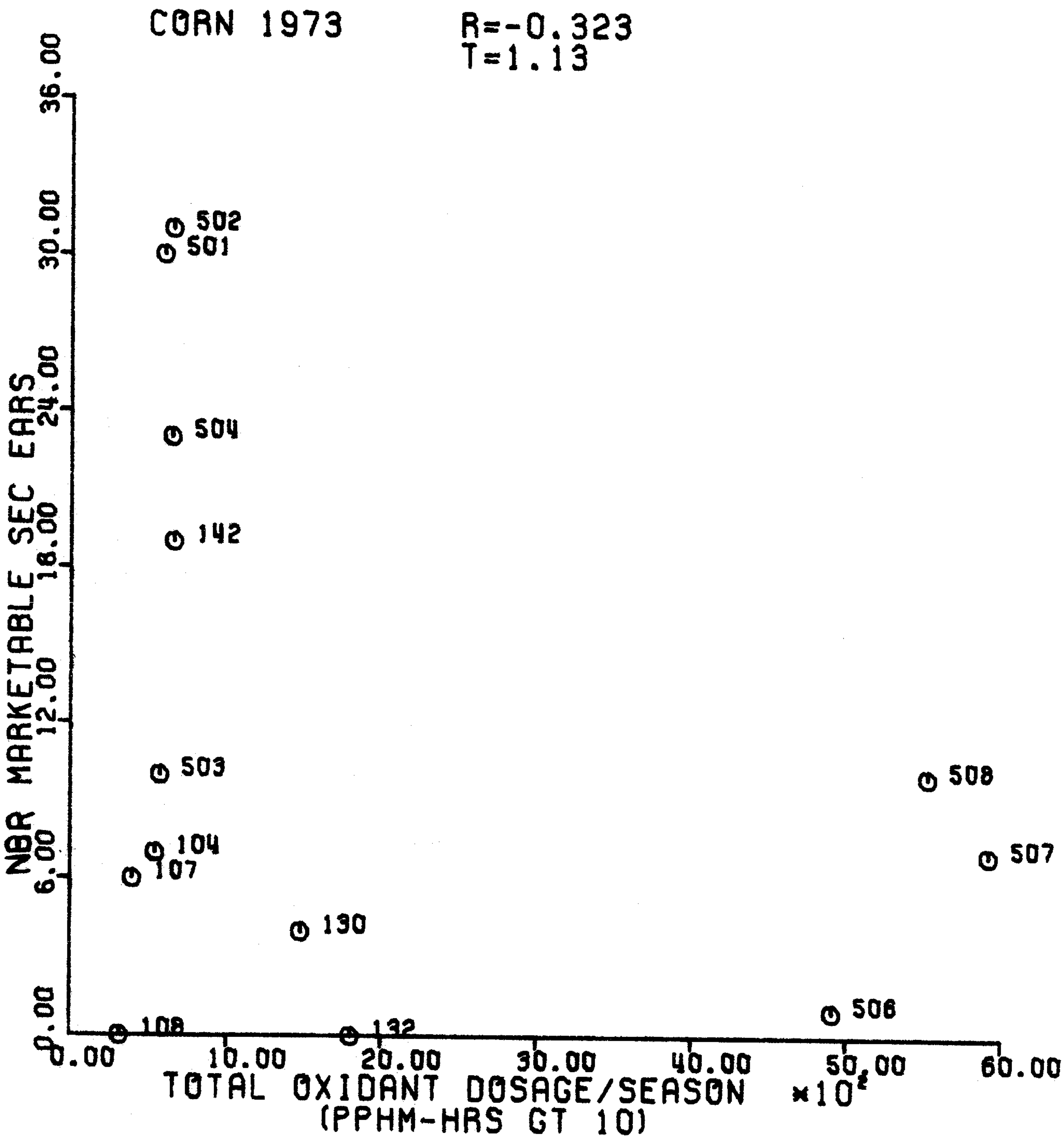


Figure 14. Correlation of plant heights of field and test plot Golden Jubilee corn with the total ambient dosage present during growth.

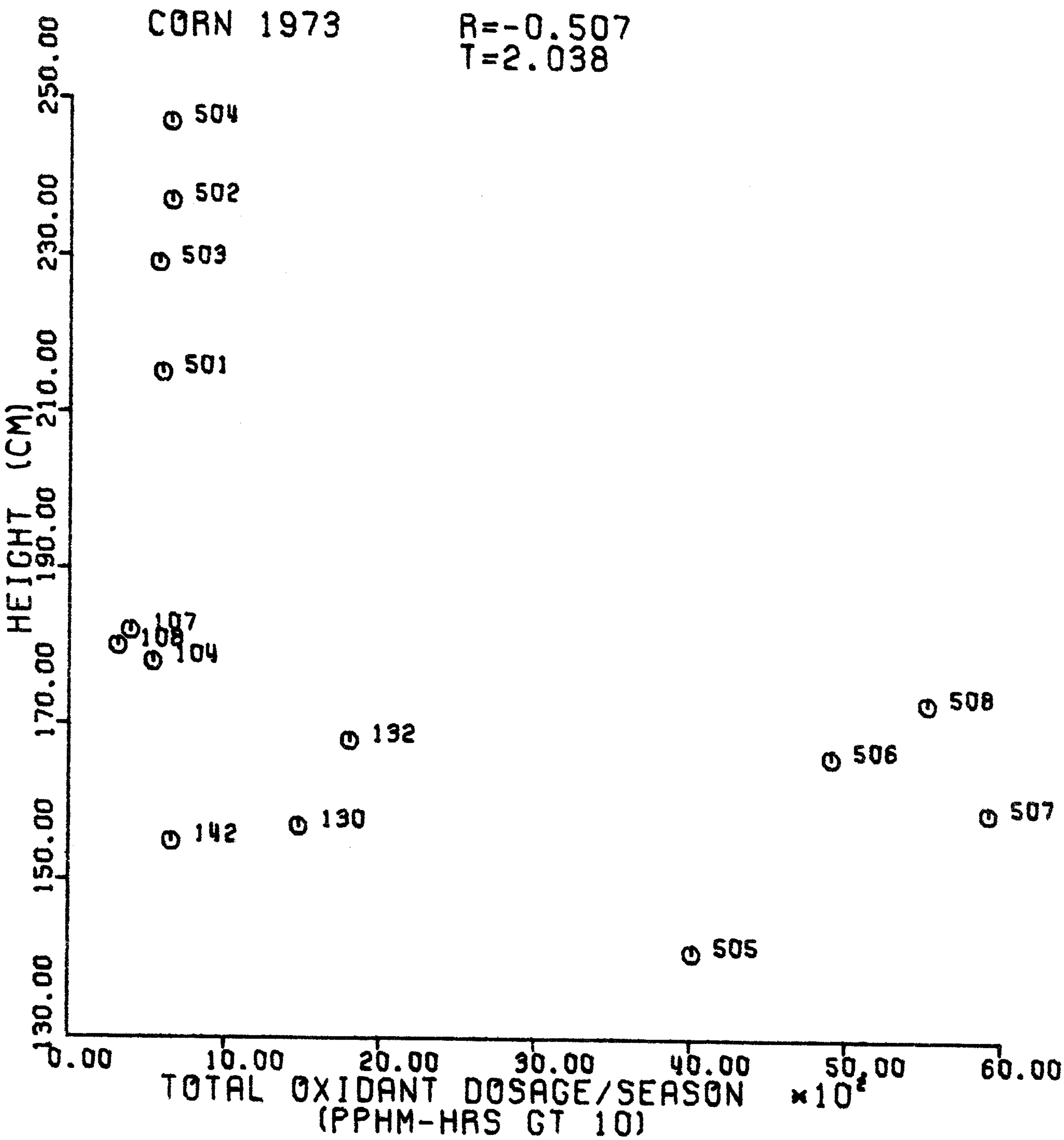


Figure 15. Correlation of the extent of kernel shrivel on harvested Golden Jubilee corn ears from field and test plots with the total ambient dosage present during growth.

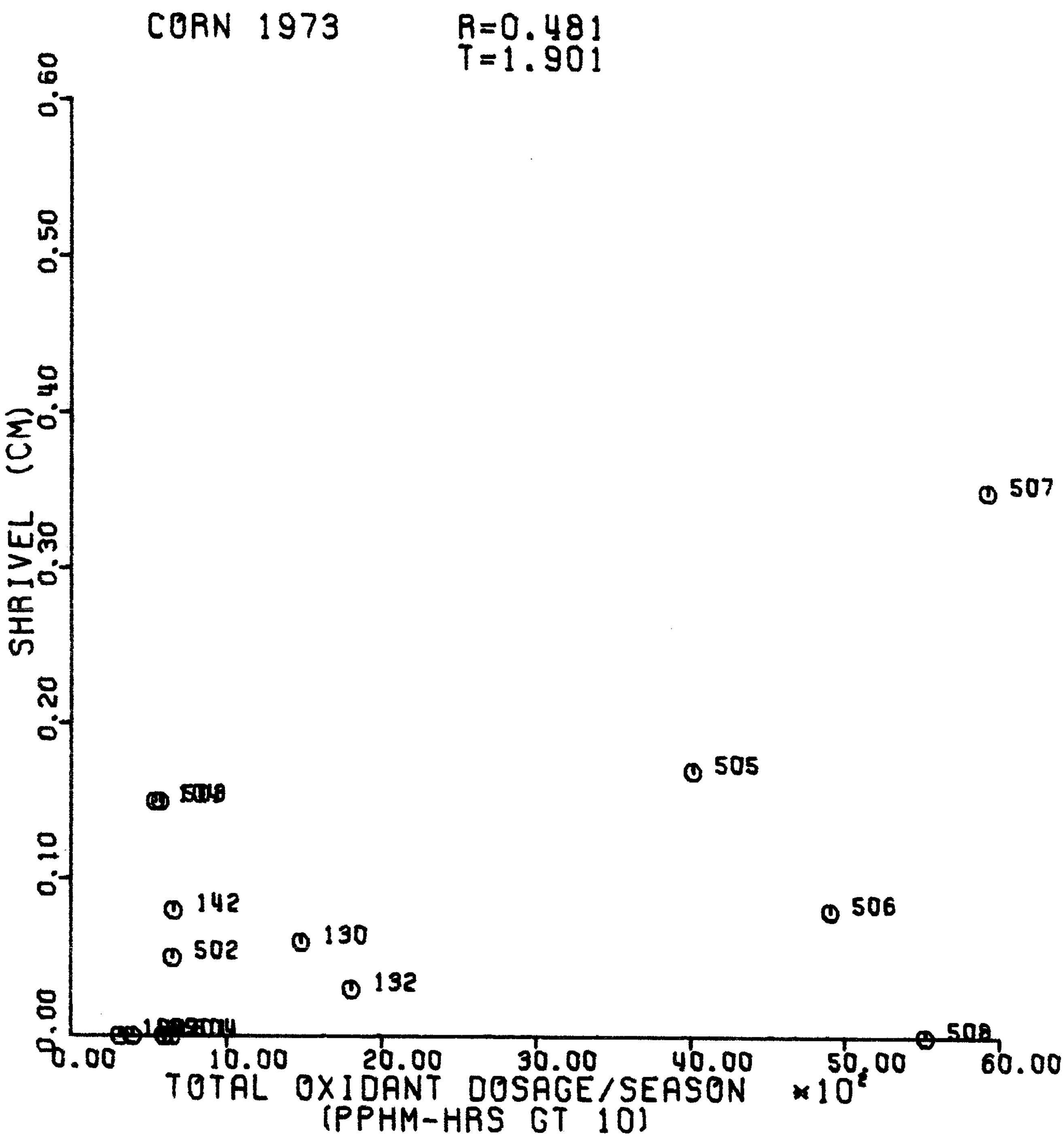


Figure 16. Correlation of lengths of harvested Golden Jubilee corn ears from field and test plots with the total ambient dosage present during growth.

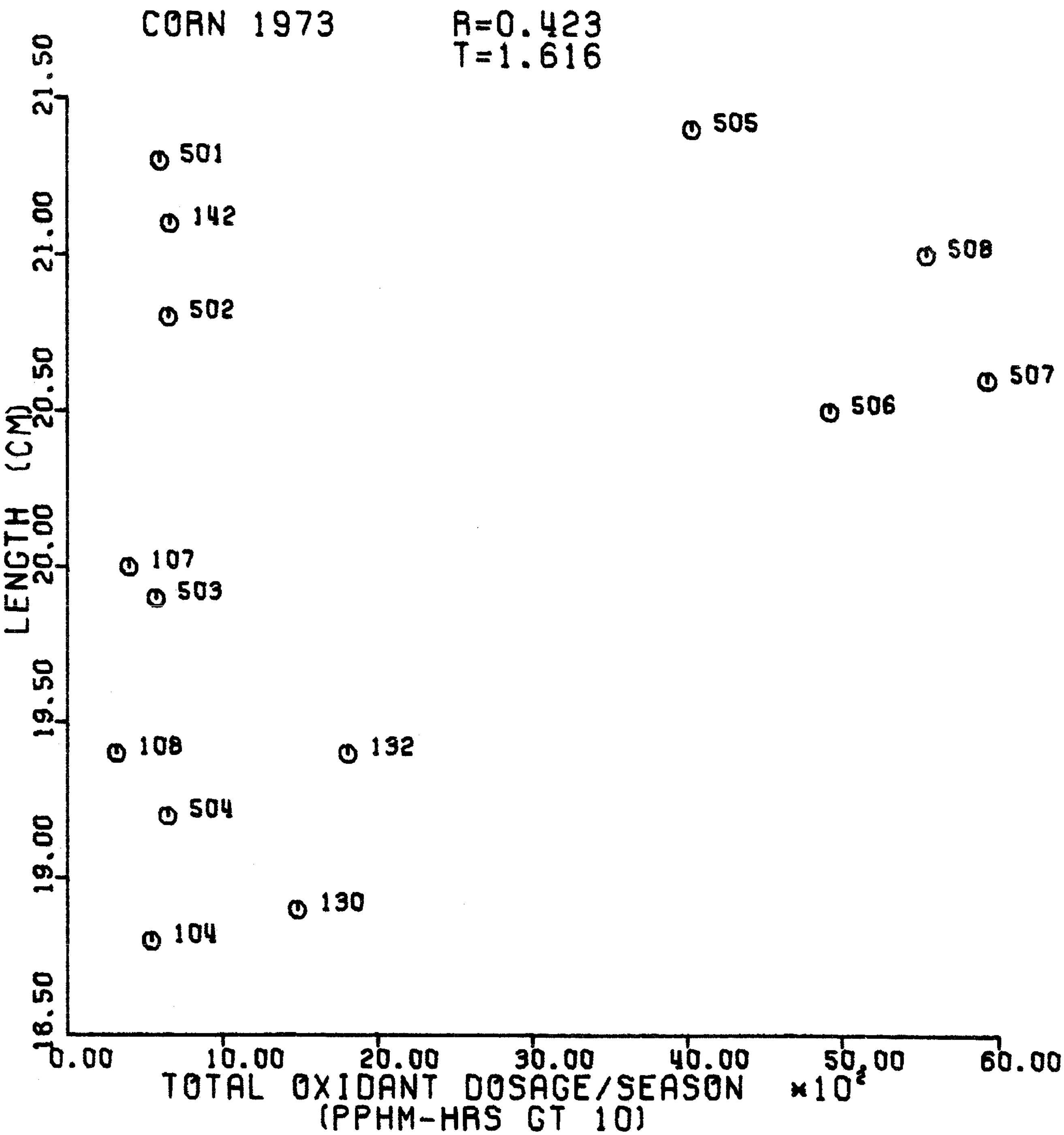
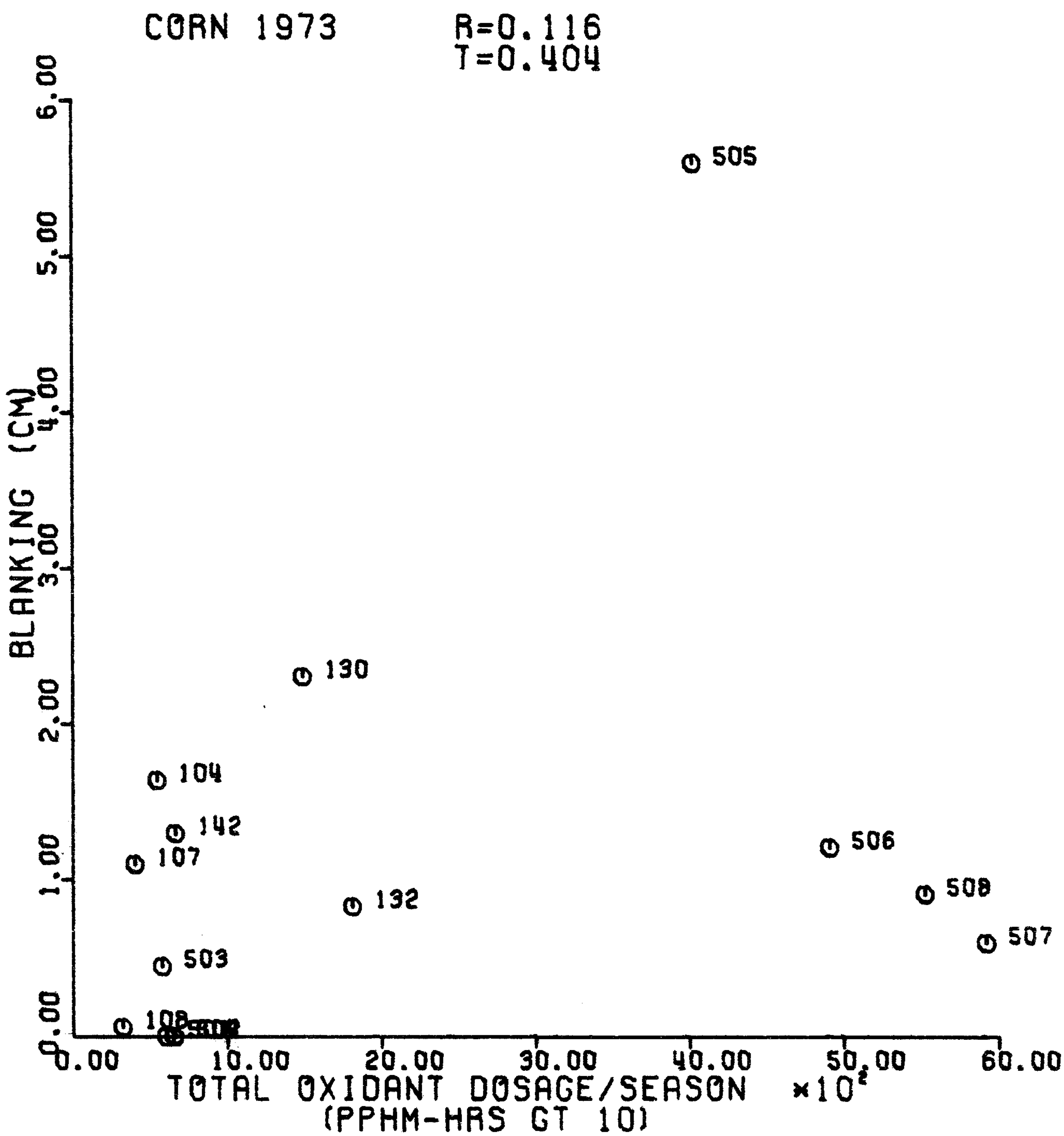


Figure 17. Correlation of the extent of kernel blanking on harvested Golden Jubilee corn ears from field and test plots with the total ambient dosage present during growth.



Introduction

H-11 pole tomatoes are a multiple harvest crop extending over a three month harvest period in the South Coast Air Basin. The number of fruit produced per plant and the hand labor involved in harvesting over such an extended period precluded using a large number of yield plots distributed throughout the study area. Three yield plots were established and harvested on a bi-weekly schedule over the harvest period with the intention of comparing yield curves at different ambient dosages. It was beyond the capability of the project to include more field locations as the amount of labor required to pick and evaluate harvests would have been excessive. These reasons effectively eliminated pole tomates as the developmental test crop.

Long-Term Ozone Fumigation

Treatments: 0 ppm ozone, .25 ppm ozone, .30 ppm ozone

Exposure: Treatments were exposed to the respective concentrations of fumigant 137 out of a total 2400 hours or about 3.6% of the growing period. Fumigations were six hours in duration and at a frequency of 1.5 times a week.

Results: Dramatic reductions in the size of fumigated plants were observed on both a fresh and dry weight basis (Table 12). However, this reduction was not apparent when yields from each treatment were compared. Yields were not significantly different when measured as were number of fruit or weight of fruit harvested. It was interesting to note that the .20 ppm ozone treatment plants bore about 47% more immature fruit at harvest than control plants but had 69% less flowers. The .30 ppm treatment plants were observed to have fewer immature fruit and flowers than control plants.

The 1973 ozone fumigations utilized the same 1.5 exposures per week as the sweet corn in contrast to the three exposures per week of the 1972 study. Plants from both the 1973 fumigated treatments reacted to exposures in much the same manner as the 1972 .20 ppm treatment plants - reductions in plant size but no significant reduction in yields. One can only speculate whether the lack of yield differences was due to less frequent exposures as in the sweet corn, or whether the tolerance of H-11 tomatoes to ozone is very high.

Nutritional Analyses of 1972 Fumigation Studies (7)

All analyses were run with standard procedures utilized by the staff of the Western Regional Laboratory, United States Department of Agriculture, Berkeley, California.

I. PAN Fumigated H-11 Tomatoes

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Results: PAN had almost no effect on nutrient levels within harvested H-11 tomatoes as only the reduction in the Rb concentrations appeared to be associated with PAN levels (Table 13).

II. Ozone Fumigated H-11 Tomatoes

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Results: Ozone appeared to effect reductions in many materials within H-11 tomato fruit (Table 14). Fruit from the high fumigation treatment plants were reduced in fiber content, calories and carbohydrate levels. A significant decrease in the levels of vitamin C and thiamine was also observed. However, the concentration of measured metals did not shift among treatments to any significant degree with ozone exposure.

Field Study

Data from the commercial field of H-11 tomatoes (103) was rendered invalid by harvest crews picking through the established field plots. The enormous effort expended to prevent just such occurrences was to no avail. Posting plots with signs and marking tape and soliciting cooperation from the grower, the county agricultural inspectors and harvest crew foremen did not prevent the picking of the field plots.

Locations: Two test plots and a single commercial plot were harvested (Map 6).

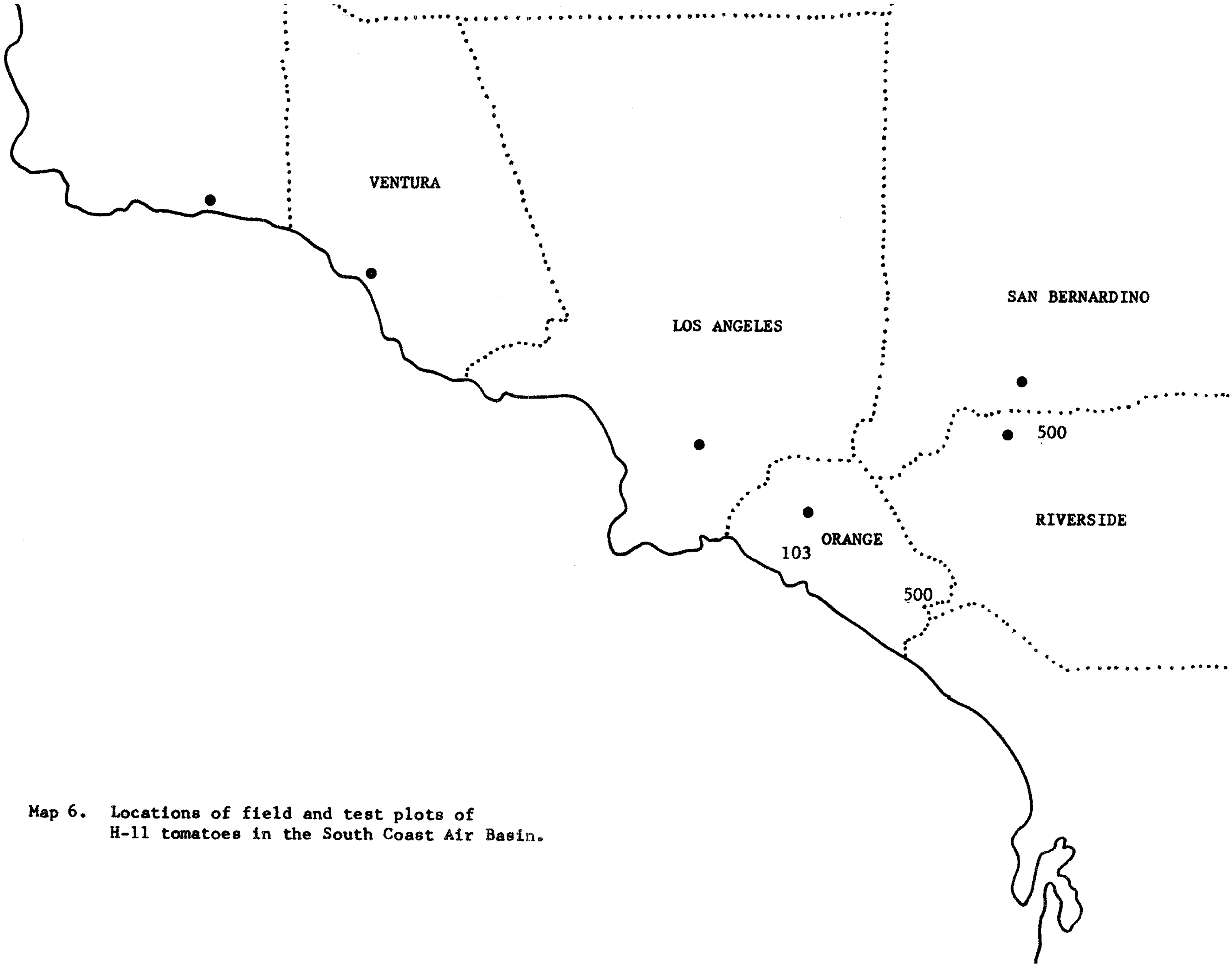
Sampling Techniques: One hundred plants were harvested biweekly at each of the two test plots. Thirty commercial plants were selected and harvested biweekly on the commercial field plot. Fifty fruits were taken at random from each harvest and evaluated and the total number and weight of harvest recorded.

Results: A comparison of the South Coast Field Station and UCR test plots on a seasonal level indicated that fruits taken from the SCF test plot were generally produced in greater number, were larger and of better quality (Figures 18 - 32). The commercial plot is also shown but is not comparable and correlations should be ignored.

South Coast Field Station produced a greater yield per plant on a seasonal basis when measured by number of fruit and total weight of fruit picked (Figures 33 - 36). The UCR plot produced 34% fewer fruit weighing 40% less than the total harvested weight of the South Coast Field Station plot. This trend was visible in plots of the number, weight, and average weight of fruit for each harvest (Figures 37 - 42). The critical question of whether ozone dosages caused such differences was not clear since only two viable locations were available. Correlations of the measured variables at each harvest and the corresponding ozone dosages produced some significant correlations but little definitive data (Figures 43 - 66). A natural decline in vigor over the harvest season may have been responsible and would not be distinguishable from ozone affected reductions.

Discussion

The loss of the Moreno test plot reported in the April 1974 Semi-Annual Report and the commercial field plot reduced the effective number of field locations to two. However, even if such losses had been avoided it would be doubtful if four locations would have been any more definitive on a statistical level. A multiple harvest crop such as pole tomatoes would require a comparable number of field locations as the sweet corn (14), an impossible level of field work considering the six other crops being studied. This work could only be completed if a single crop were studied and all plantings maintained and harvested by project personnel.



Map 6. Locations of field and test plots of H-11 tomatoes in the South Coast Air Basin.

Table 12. Summary of significant ozone effects on H-11 tomatoes as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		No. Suckers		No. Immature Fruit			Total Fresh Wt. Plant			Total Dry Wt. Plant		
Ozone	0	-	a[1]	-	a	AB[2]	-	a	A	-	a	A
Treatments	.25	-	a	-46.8[3]	b	A	22.6	b	B	27.5	b	B
(ppm)	.30	-	a	25.5	a	B	35.7	c	B	41.0	c	B

		No. Flowers			Fresh Wt. Immature Fruit		Fresh Wt. Fruit, Leaves, Stems		
Ozone	0	-	a	A	-	a	-	a	A
Treatments	.25	69.6	b	B	-	a	6.4	a	A
(ppm)	.30	52.2	b	AB	-	a	34.6	b	B

		Dry Wt. Leaves, Stems			Dry Wt. Roots			No. Dead Leaves		
Ozone	0	-	a	A	-	a	A	-	a	A
Treatments	.25	27.0	b	B	32.7	b	B	-48.4	b	A
(ppm)	.30	40.7	b	B	44.5	b	B	-151.6	c	B

		Mean No. Fruit Harvested/Plant		Mean Wt. of Fruit Harvested/Plant		Avg. Wt. of Fruit/Treatment	
Ozone	0	-	a	-	a	-	a
Treatments	.25	-	a	-	a	-	a
(ppm)	.30	-	a	-	a	-	a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 13. Summary of the effects of PAN on nutritional constituents in the fruit of H-11 tomatoes as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Solids	Water	Protein	Carbohydrates	Calories	Fiber
PAN	0	- a[1]	- a	- a	- a	- a	- a
Treatments	20	- a	- a	- a	- a	- a	- a
(ppb)	40	- a	- a	- a	- a	- a	- a

		Ash	Niacin	Riboflavin			Thiamine Thiochrome	Vitamin A
PAN	0	- a	- a	-	a	A[2]	- a	- a
Treatments	20	- a	- a	-25.83[3]	b	A	- a	- a
(ppb)	40	- a	- a	-6.62	ab	A	- a	- a

		Vitamin C			N	Mn	Fe	Zn	Pb	Br	Rb		
PAN	0	-	a	A	- a	- a	- a	- a	- a	- a	-	a	A
Treatments	20	-25.2	b	B	- a	- a	- a	- a	- a	- a	3.62	a	A
(ppb)	40	-	a	A	- a	- a	- a	- a	- a	- a	21.71	b	A

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 14. Summary of the effects of ozone on nutritional constituents in the fruit of H-11 tomatoes as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Solids			Water			Fiber			Ash		
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Treatments	.20	2.0	a	A	-0.15[3]	a	A	1.1	a	A	-4.4	ab	A
(ppm)	.35	26.4	b	B	-2.0	b	B	26.9	b	B	-17.8	b	A

		Protein		Calories			Carbohydrates			Niacin		Riboflavin	
Ozone	0	-	a	-	a	A	-	a	A	-	a	-	a
Treatments	.20	-	a	2.6	a	A	2.8	a	A	-	a	-	a
(ppm)	.35	-	a	27.45	b	B	33.9	b	B	-	a	-	a

		Vitamin C			Vitamin A		Thiamine Thiochrome			Thiamine Microbiol		
Ozone	0	-	a	A	-	a	-	a	A	-	a	A
Treatments	.20	-1.44	a	A	-	a	14.99	b	A	14.15	b	B
(ppm)	.35	24.42	b	B	-	a	33.78	c	B	30.26	c	C

		N		Mn		Fe		Cu		Zn		Pb		Br		Rb	
Ozone	0	-	a	-	a	-	a	-	a	-	a	-	a	-	a	-	a
Treatments	.20	-	a	-	a	-	a	-	a	-	a	-	a	-	a	-	a
(ppm)	.35	-	a	-	a	-	a	-	a	-	a	-	a	-	a	-	a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significatnly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Figure 18. Correlation of seasonal yield (total number) of H-11 tomato fruit harvested at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

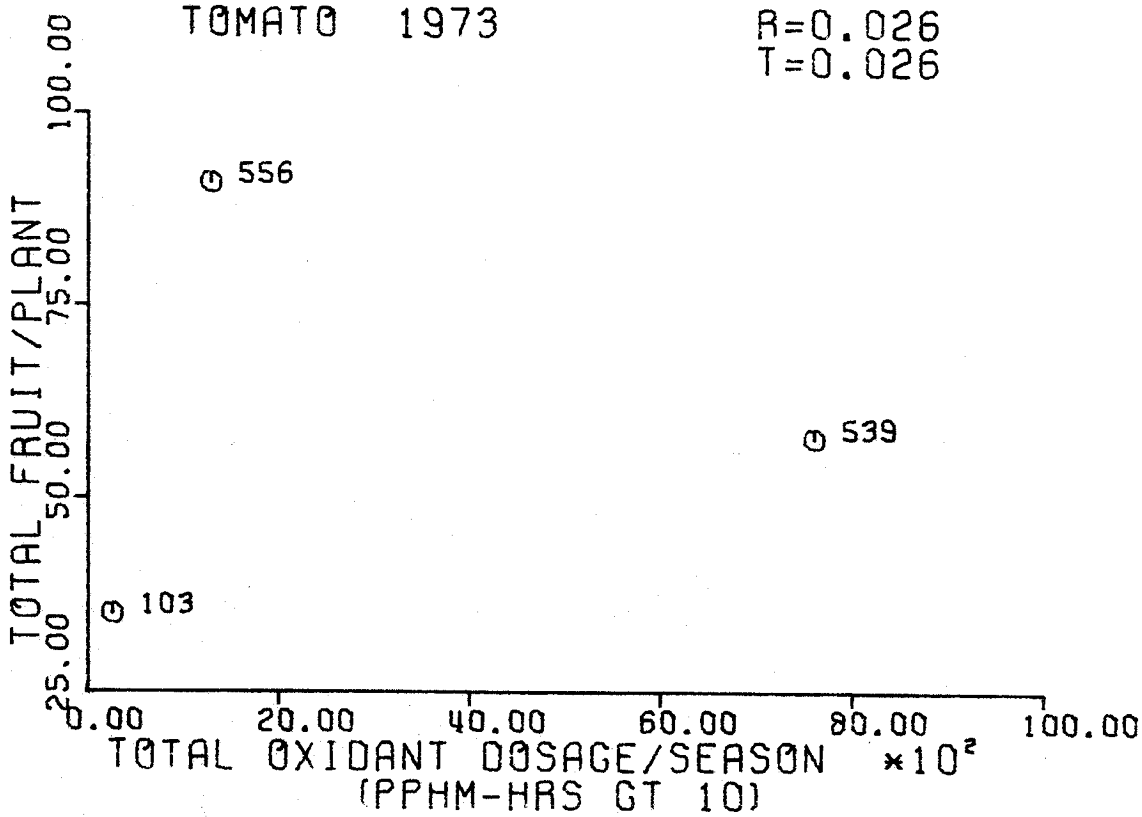


Figure 19. Correlation of seasonal yield (total weight) of H-11 tomato fruit harvested at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

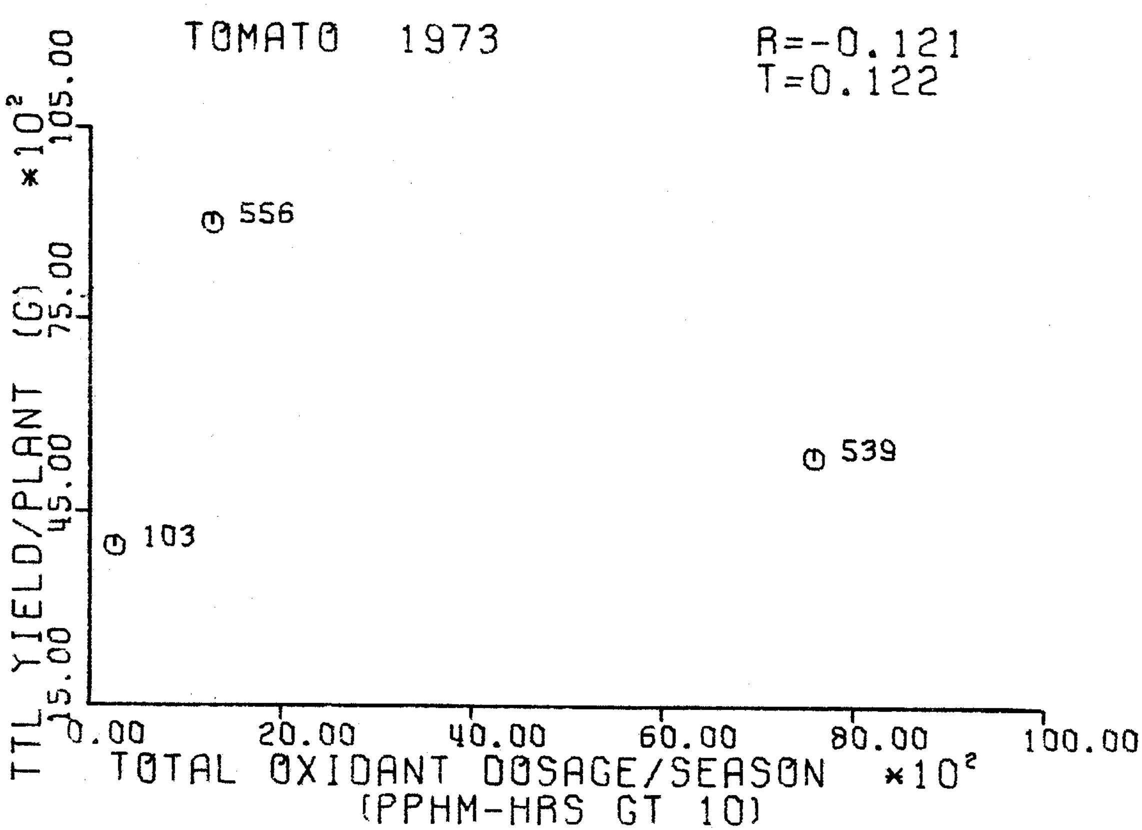


Figure 20. Correlation of average seasonal weights (weight per plant/number per plant) of harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

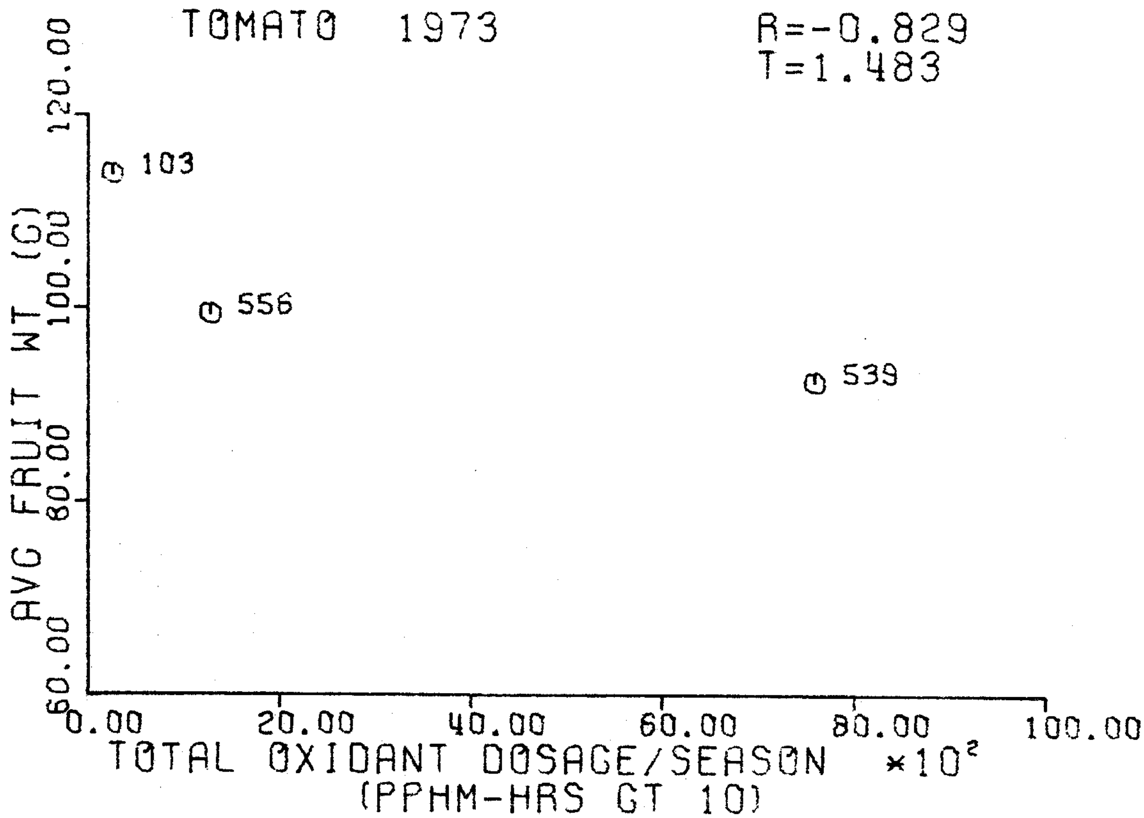


Figure 21. Correlation of average seasonal heights of harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

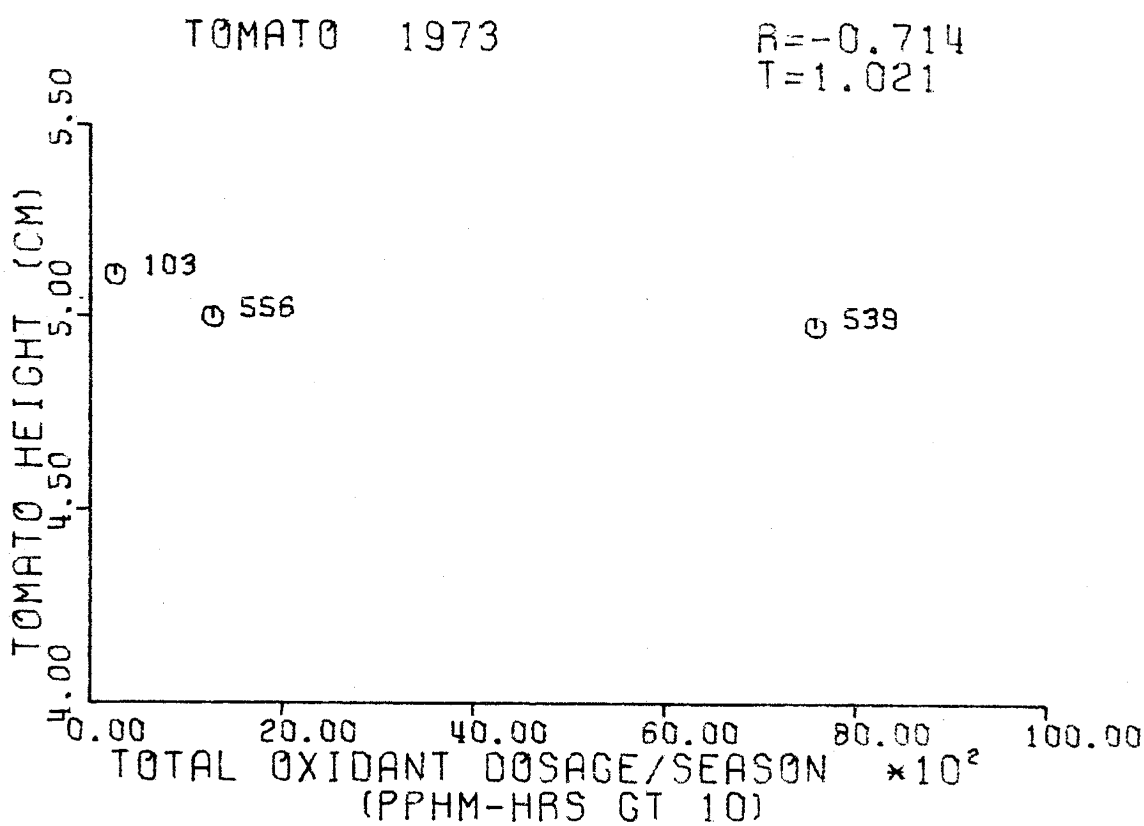


Figure 22. Correlation of average seasonal diameters of harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

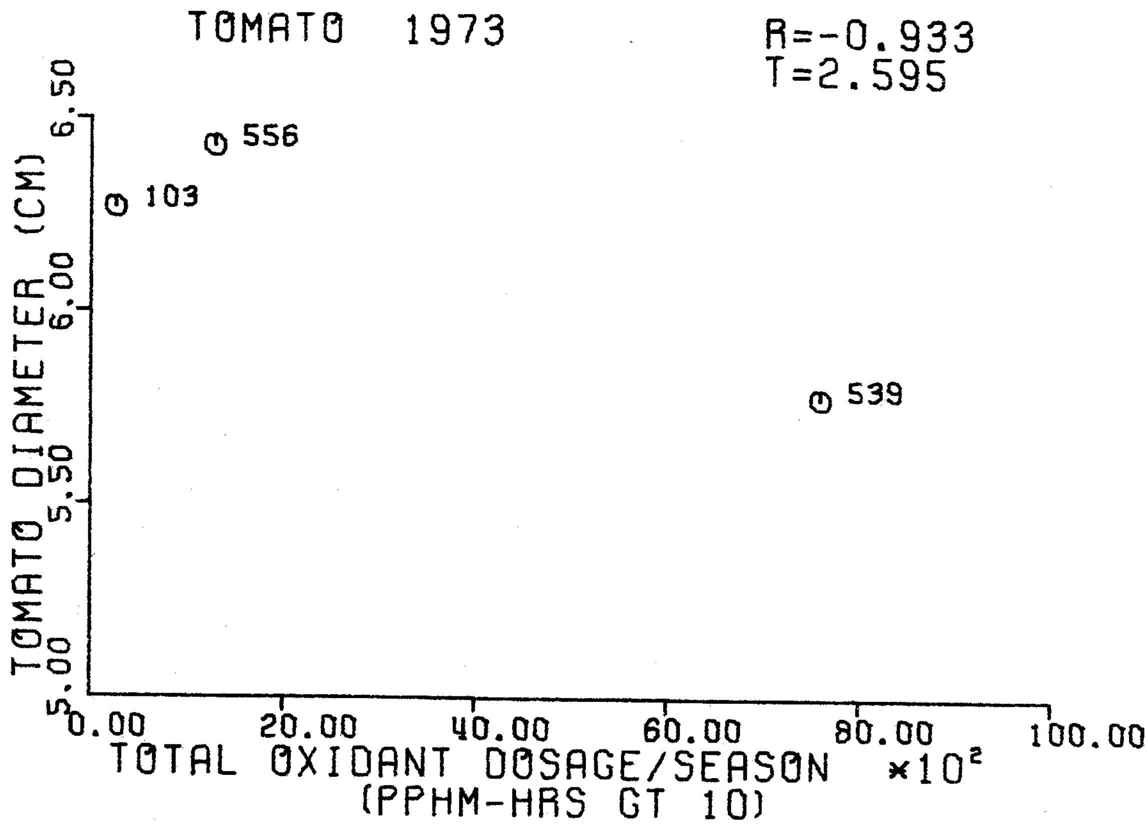


Figure 23. Correlation of average seasonal weights of harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

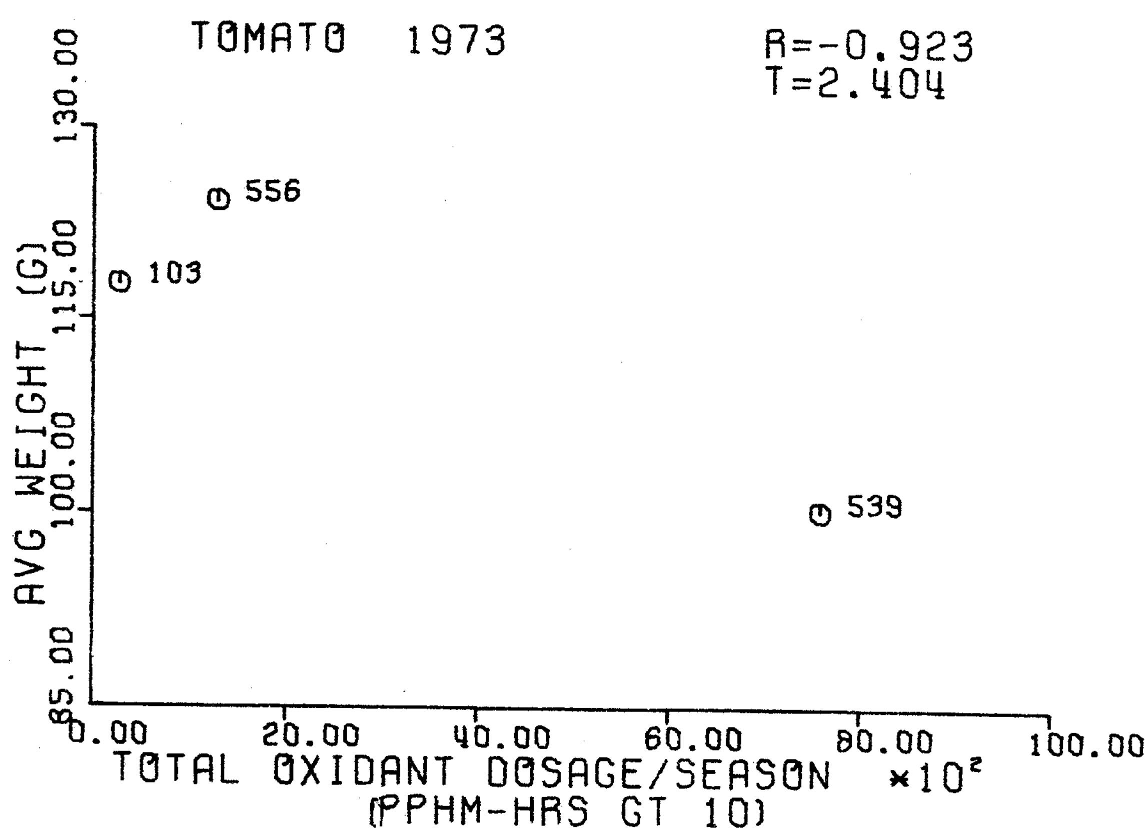


Figure 24. Correlation of average seasonal number of creases on harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

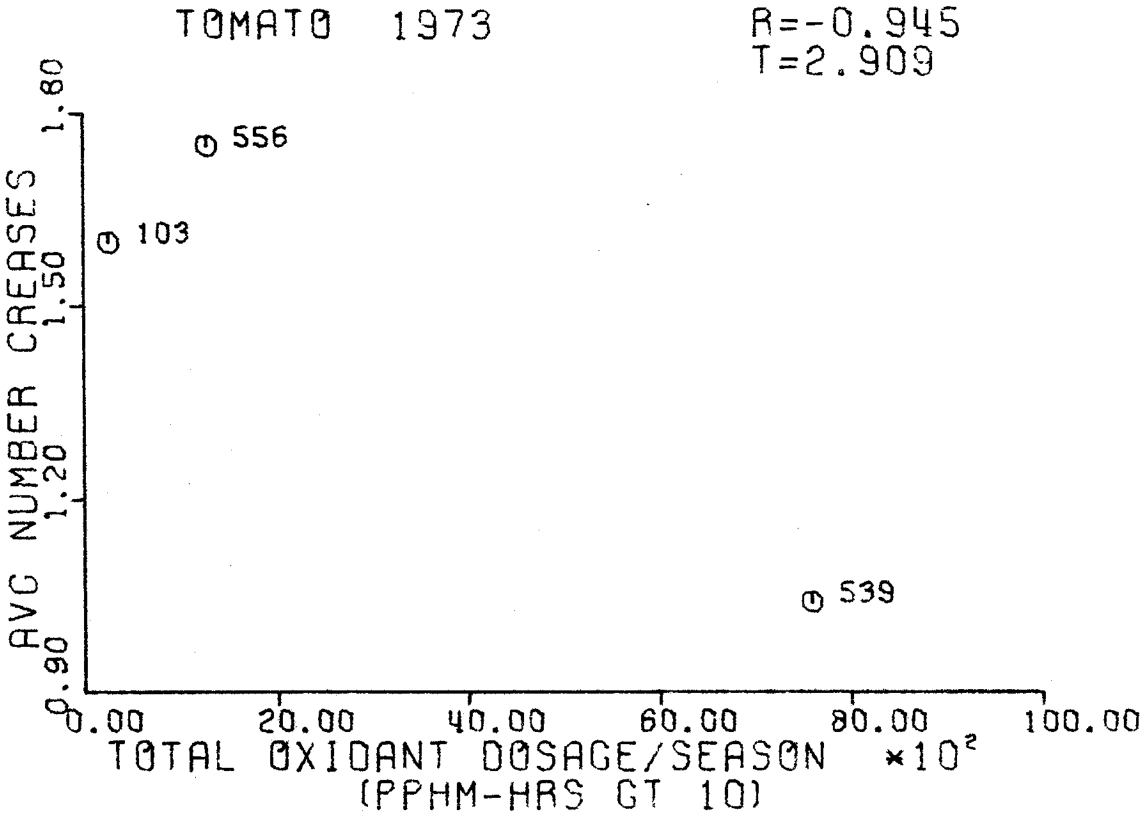


Figure 25. Correlation of average seasonal length of creases on harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

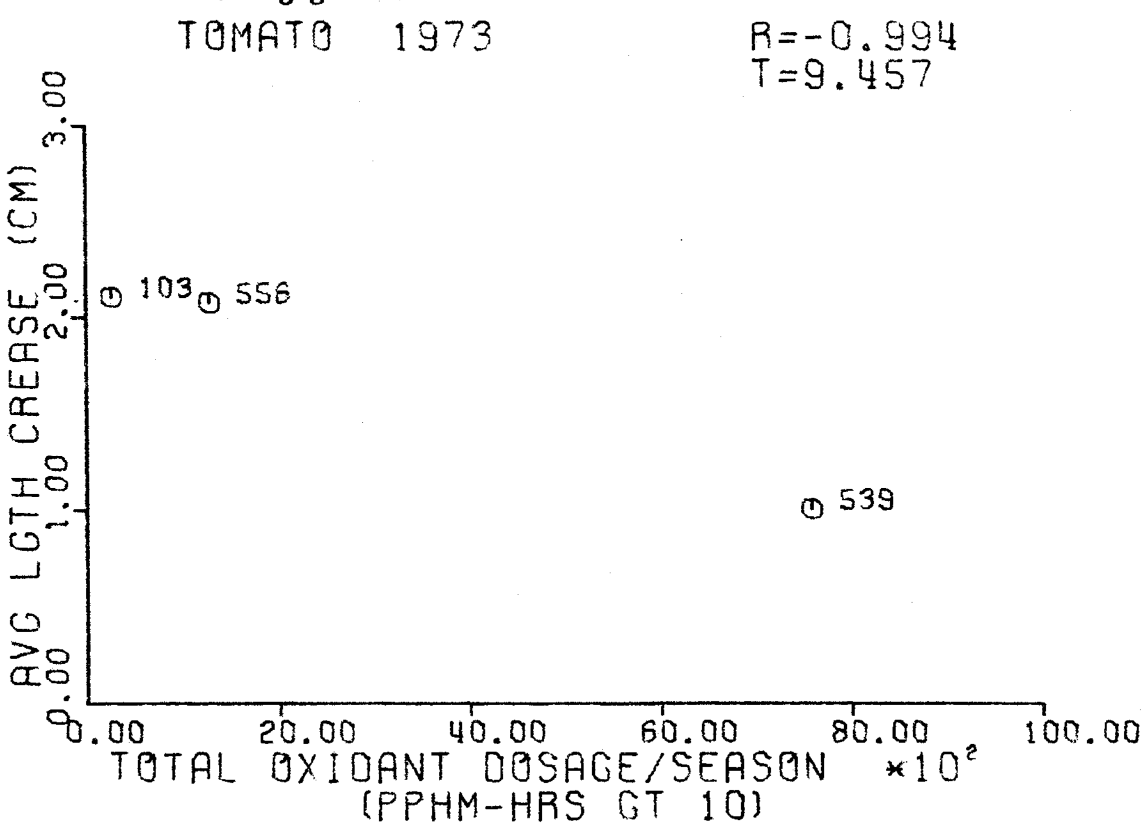


Figure 26. Correlation of average seasonal number of growth cracks on harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

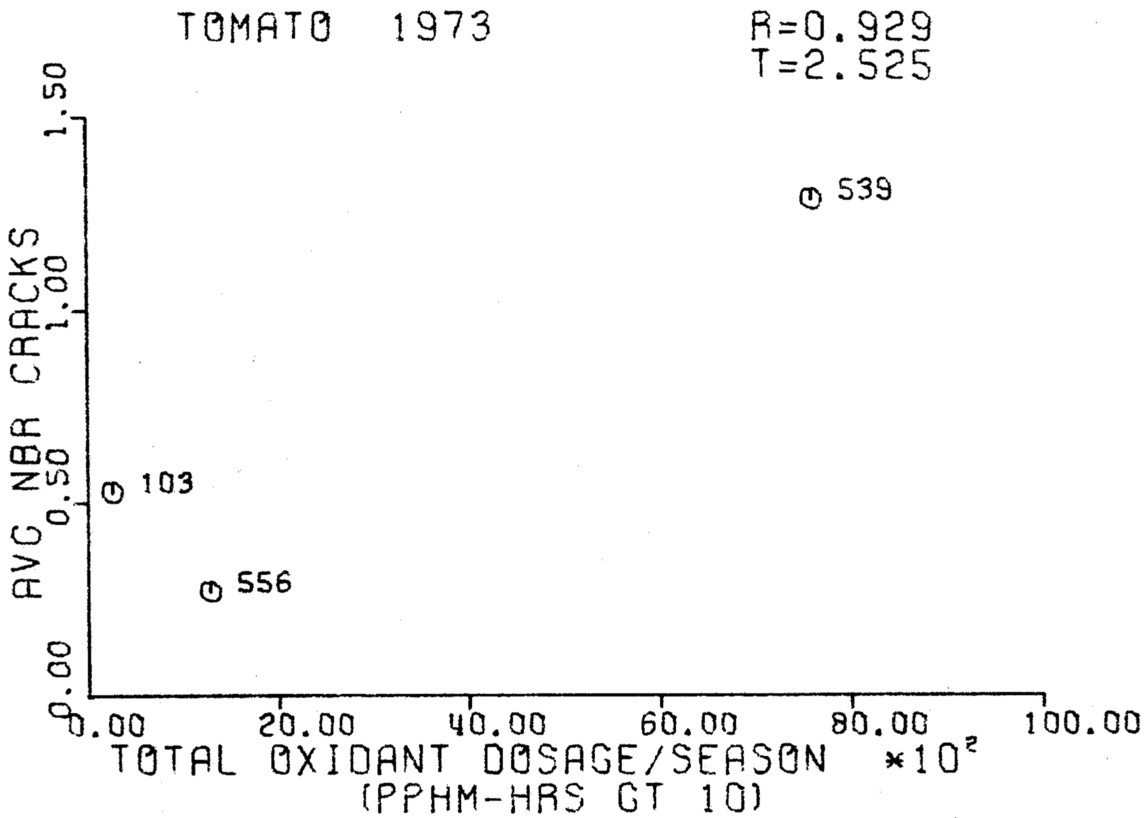


Figure 27. Correlation of average seasonal length of the longest growth cracks on harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

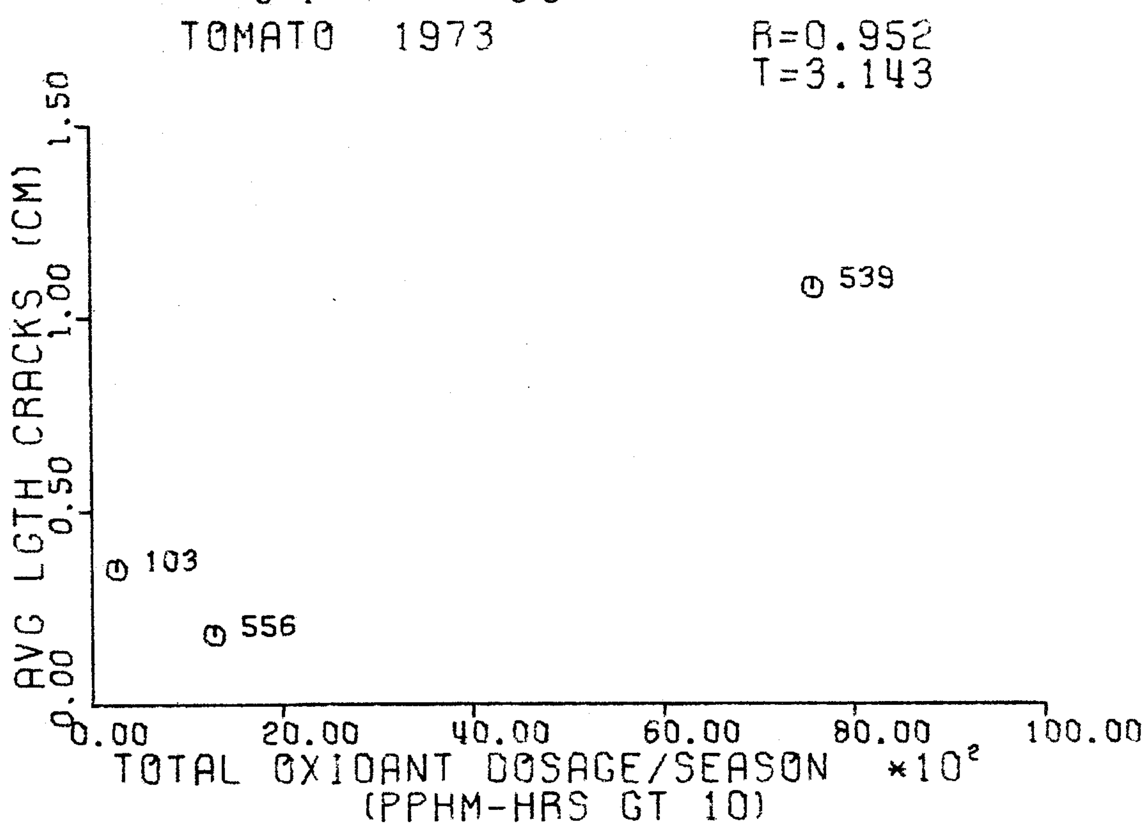


Figure 28. Correlation of average seasonal number of blemishes on harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

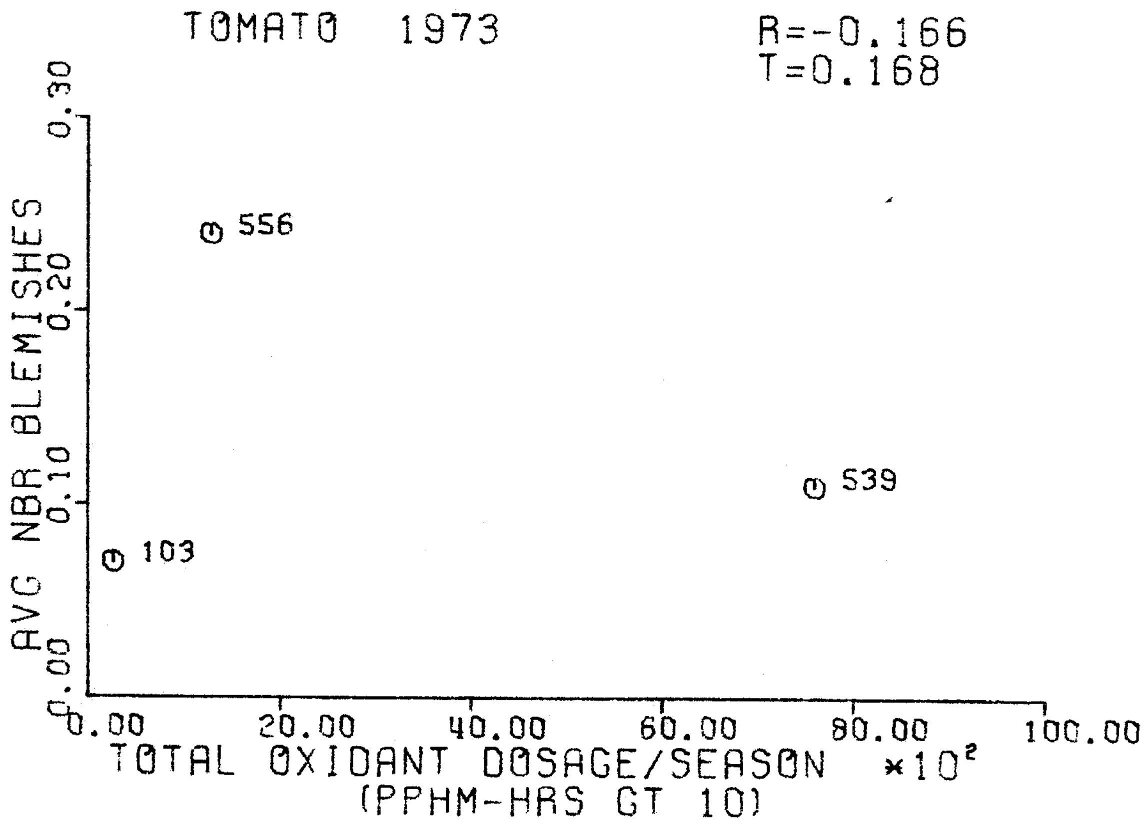


Figure 29. Correlation of average seasonal severity of blemishes on harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

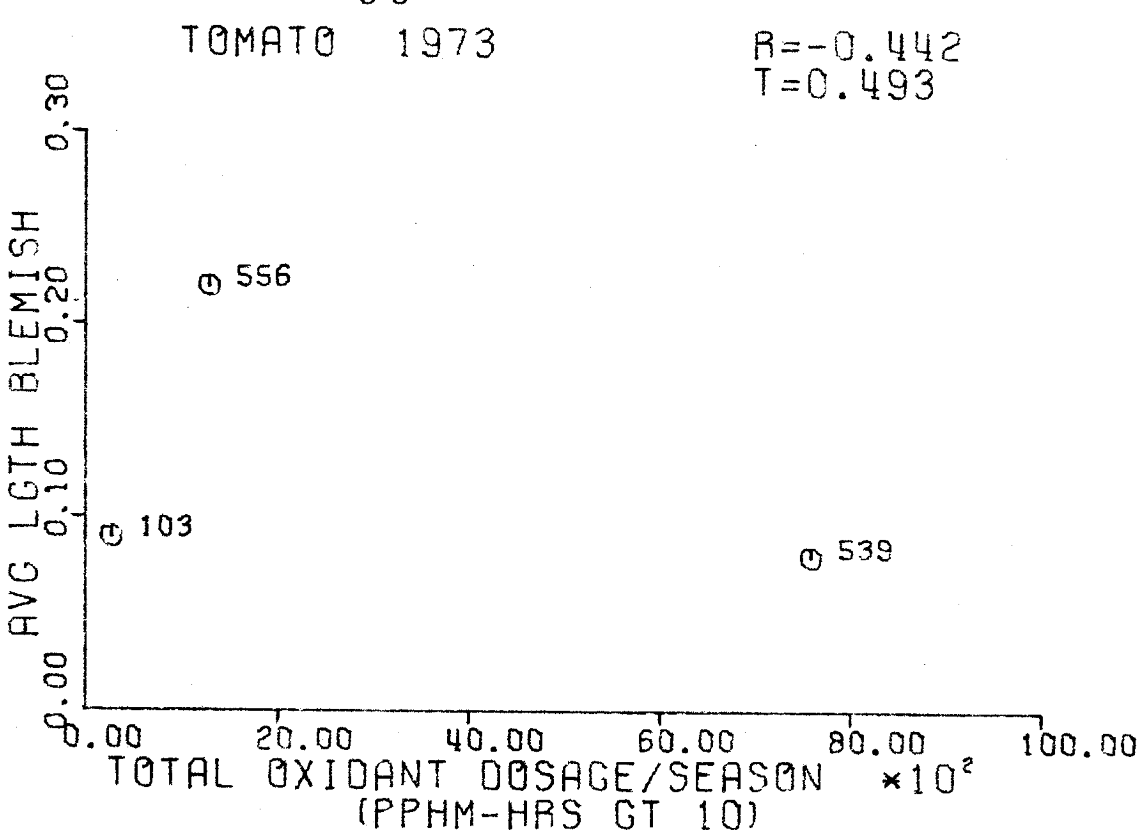


Figure 30. Correlation of average seasonal number of scars on harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

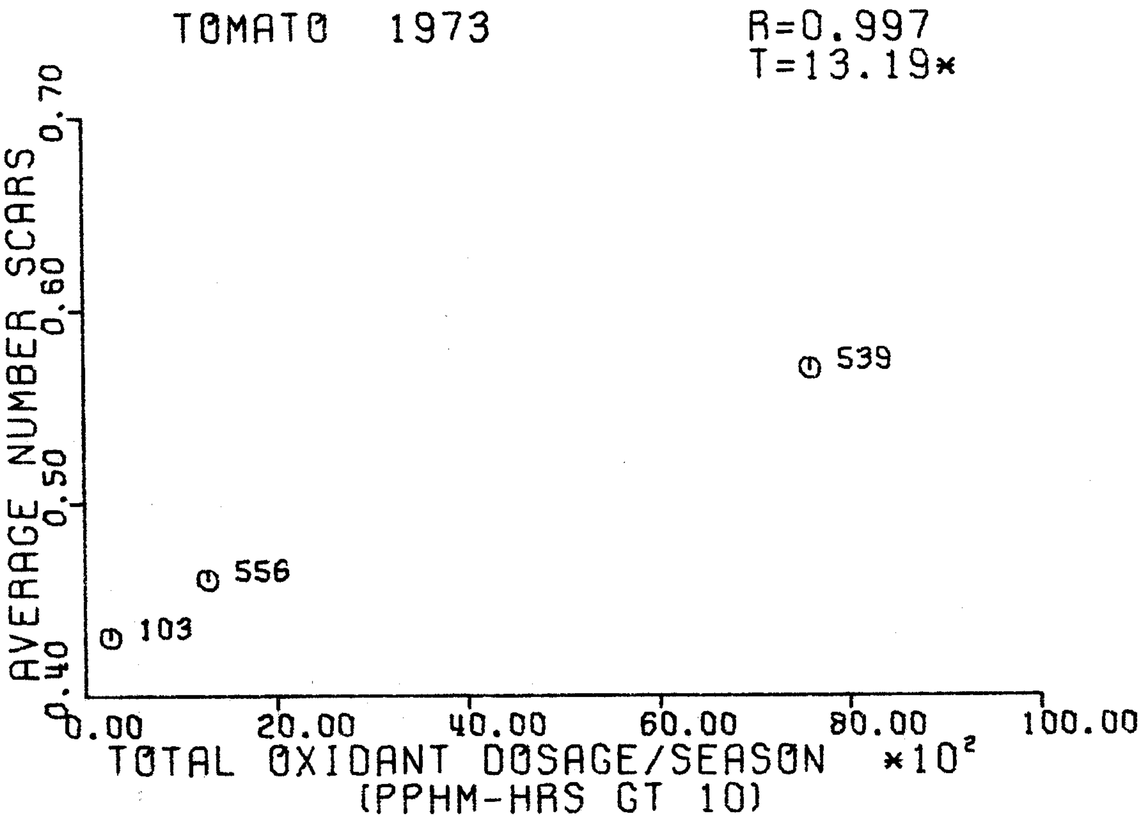


Figure 31. Correlation of average seasonal length of scars on harvested H-11 tomato fruit at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

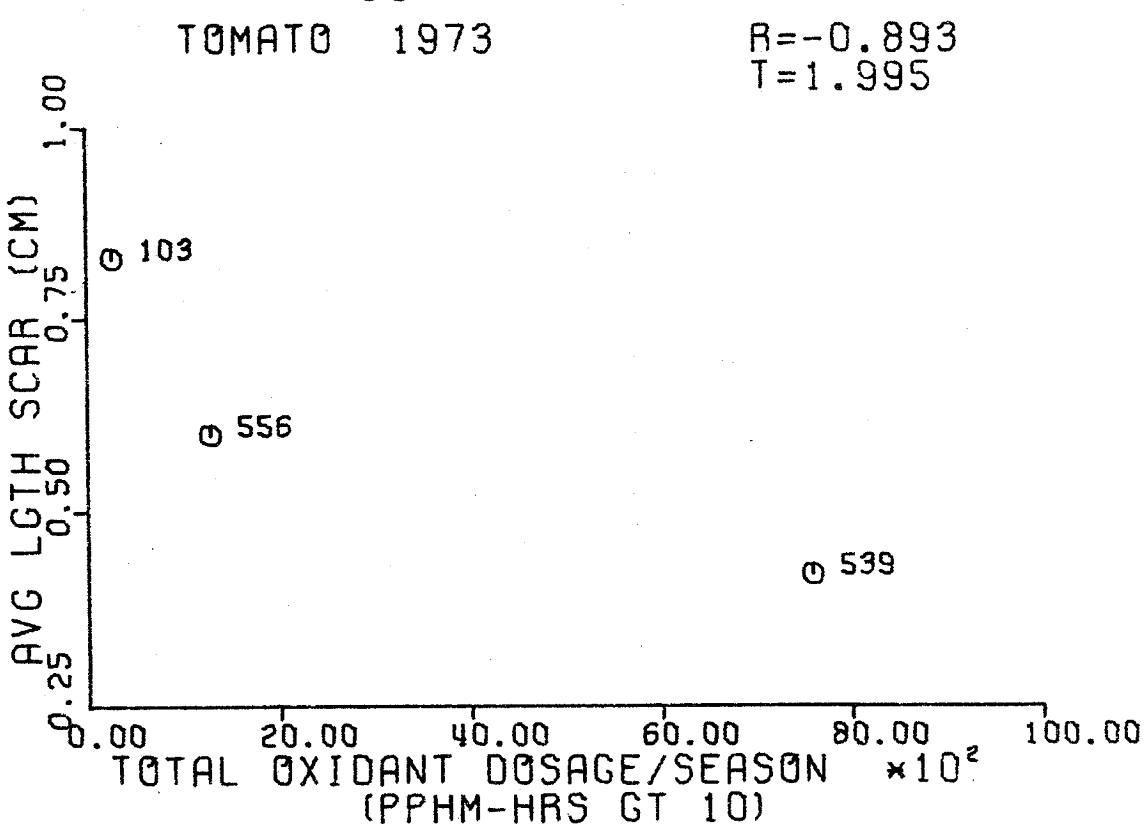


Figure 32. Correlation of average seasonal percentage of irregular H-11 tomato fruit harvested at Orange County (103), South Coast Field Station (556), and U.C.R. (539) with the total ambient oxidant dosage present during growth.

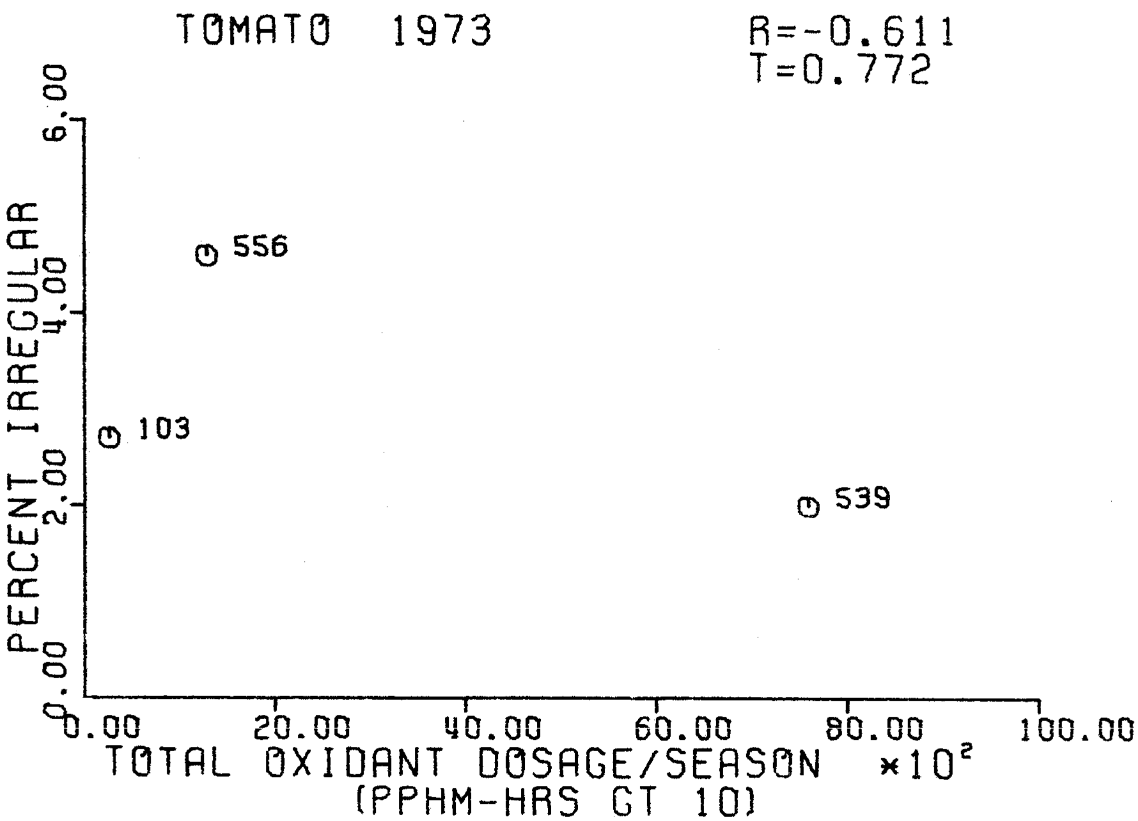


Figure 33. **Plot of the cumulative number of H-11 tomato fruit harvested at South Coast Field Station with time of harvest. The cumulative ozone dosage greater than 10 pphm was 1551 pphm hours.**

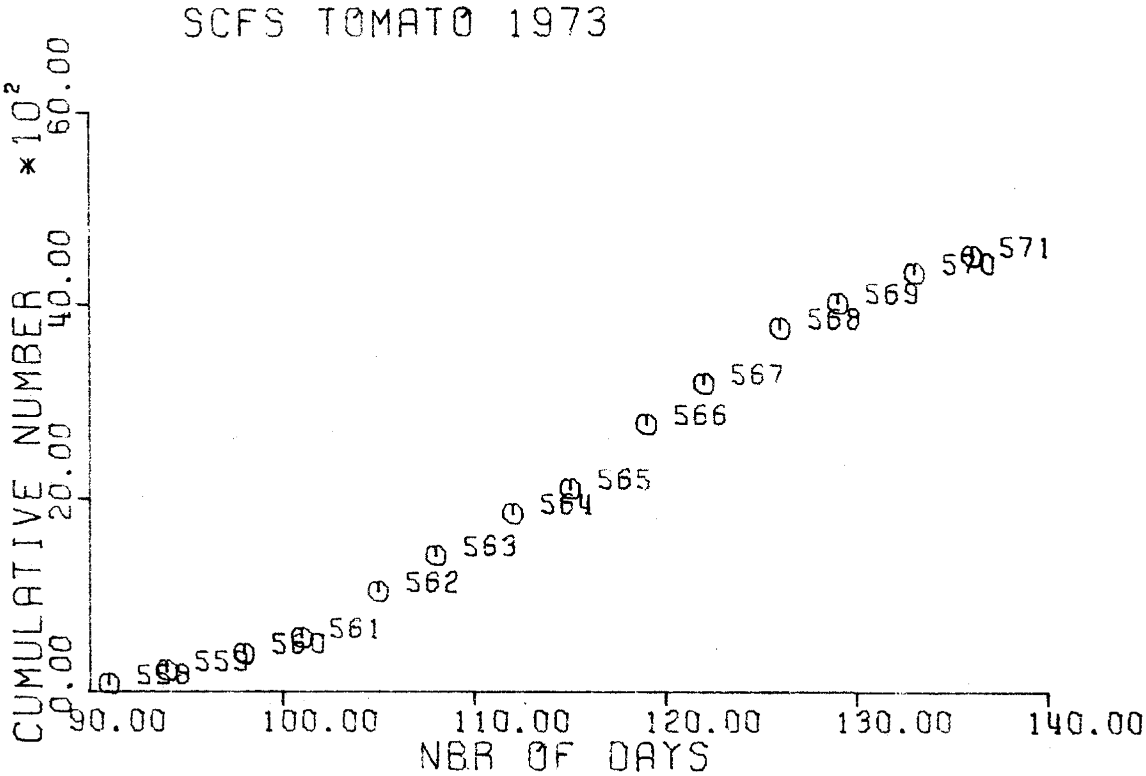


Figure 34. **Plot of the cumulative weight of H-11 tomato fruit harvested at South Coast Field Station with time of harvest. The cumulative ozone dosage greater than 10 pphm was 1551 pphm hours.**

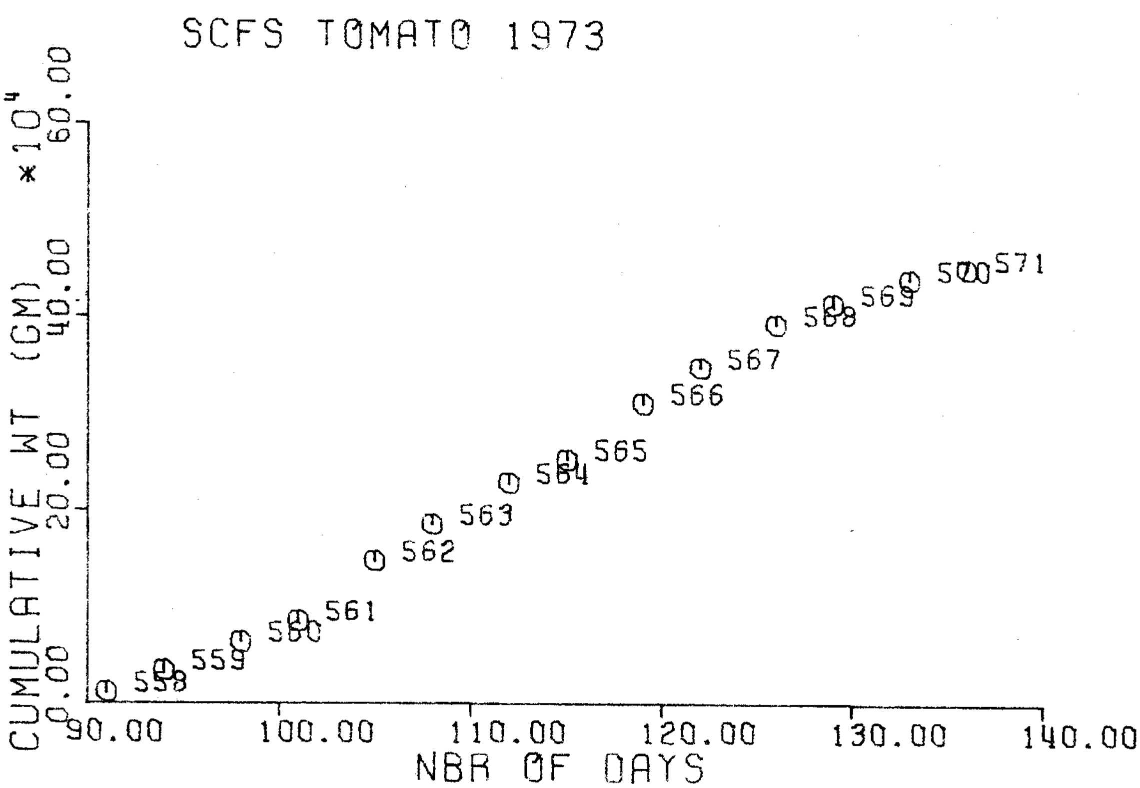


Figure 35. Plot of the cumulative number of H-11 tomato fruit harvested at U.C.R. with time of harvest. The cumulative ozone dosage greater than 10 pphm was 7667 pphm hours.

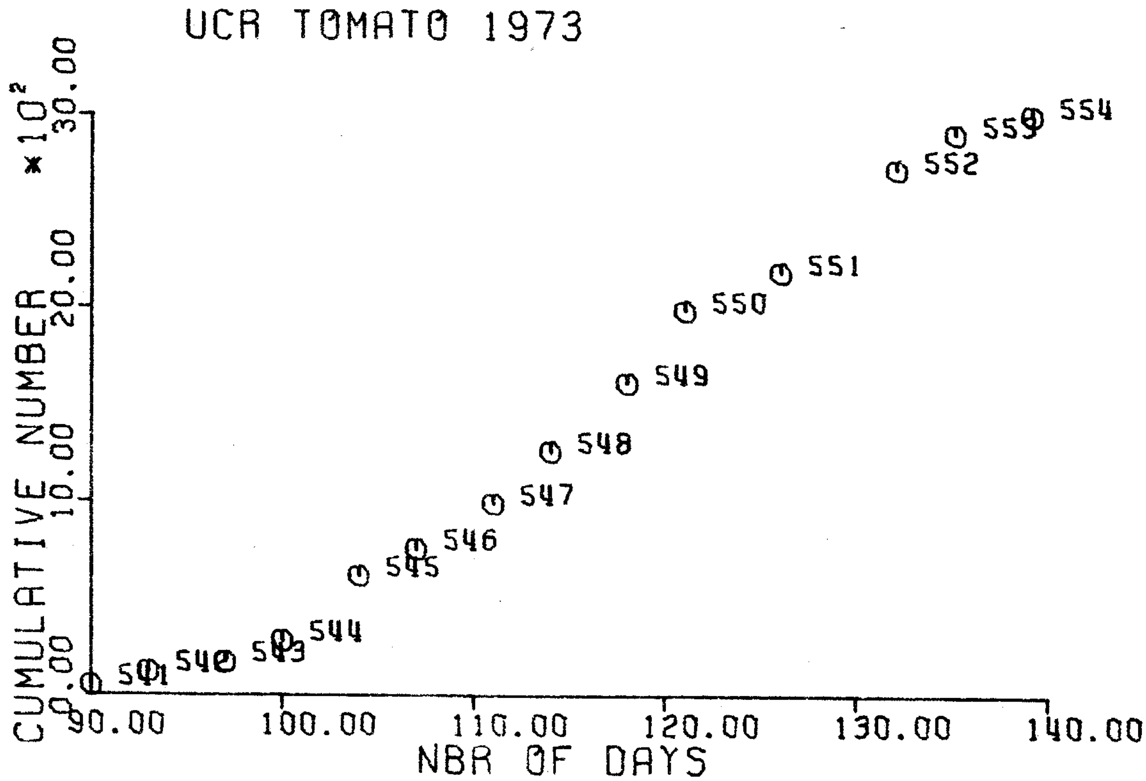


Figure 36. Plot of the cumulative weight of H-11 tomato fruit harvested at U.C.R. with time of harvest. The cumulative ozone dosage greater than 10 pphm was 7667 pphm hours.

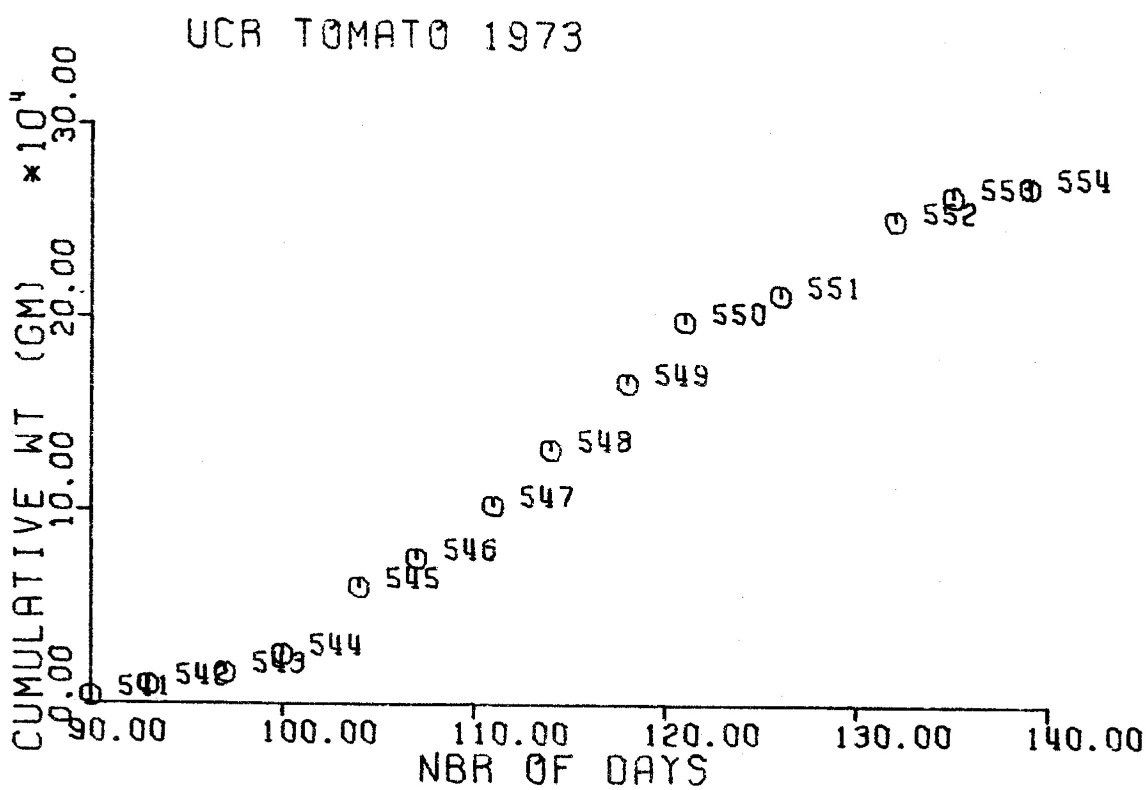


Figure 37. **Plot of the total number of H-11 tomato fruit per harvest at South Coast Field Station with time of harvest. The cumulative ozone dosage greater than 10 pphm was 1551 pphm hours.**

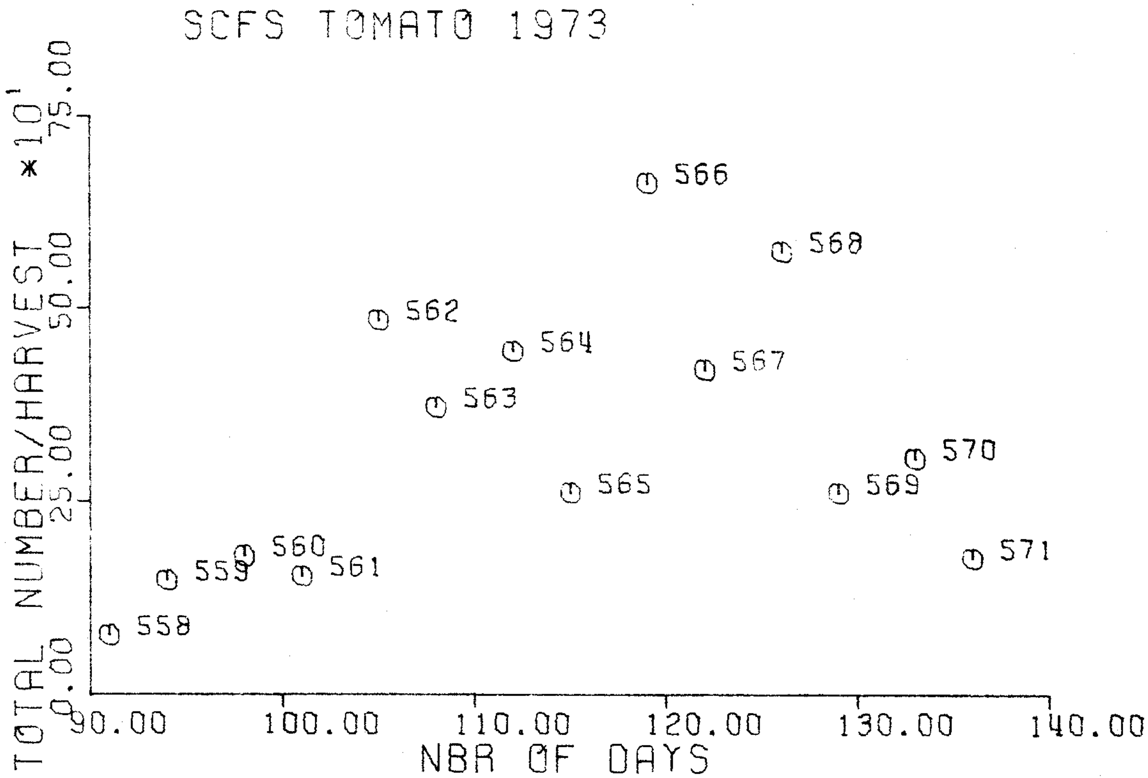


Figure 38. **Plot of the total weight of H-11 tomato fruit per harvest at South Coast Field Station with time of harvest. The cumulative ozone dosage greater than 10 pphm was 1551 pphm hours.**

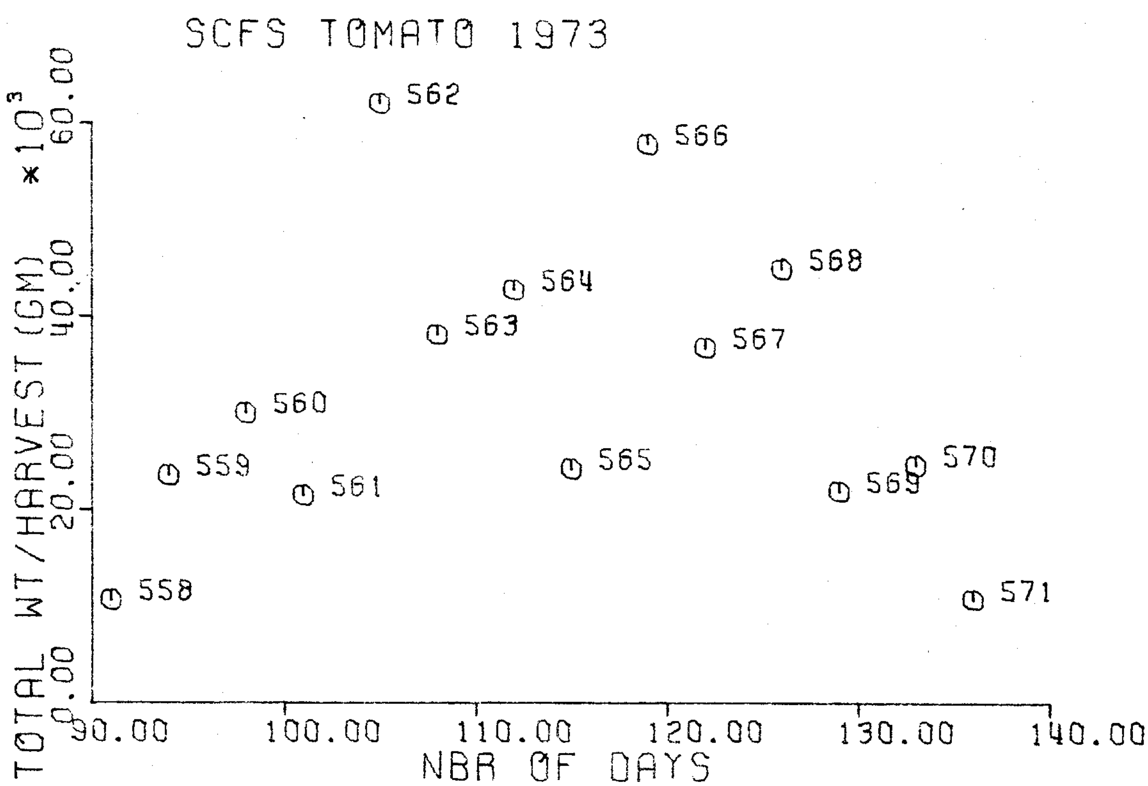


Figure 39. Plot of the total number of H-11 tomato fruit per harvest at U.C.R. with time of harvest. The cumulative ozone dosage greater than 10 pphm was 7667 pphm hours.

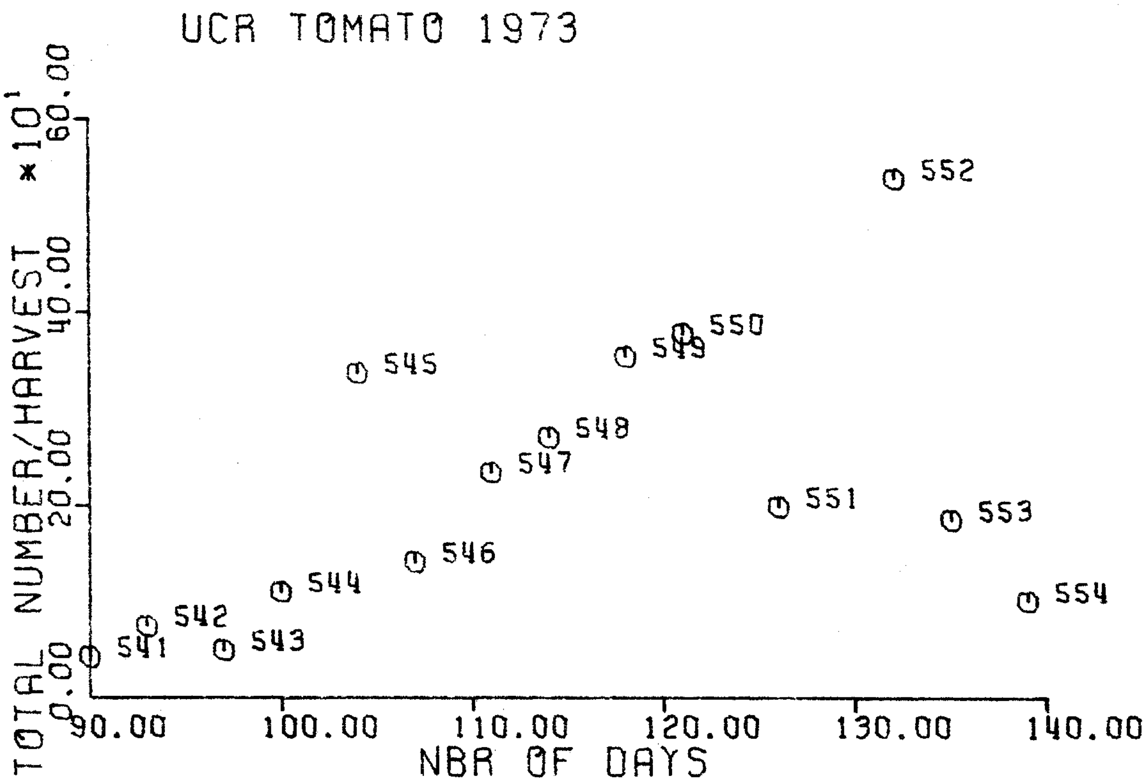


Figure 40. Plot of the total weight of H-11 tomato fruit per harvest at U.C.R. with time of harvest. The cumulative ozone dosage greater than 10 pphm was 7667 pphm hours.

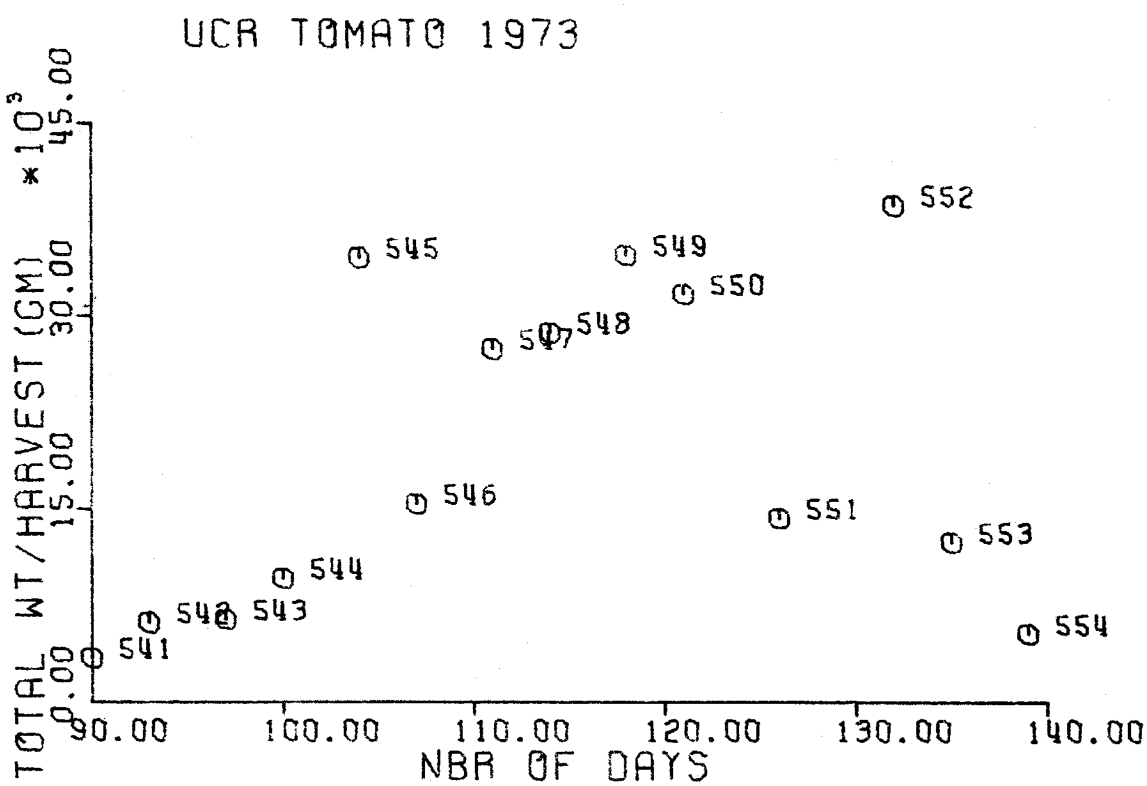


Figure 41. Plot of the average weight of H-11 tomato fruit per harvest (total wt./total number) at South Coast Field Station with time of harvest. The cumulative ozone dosage greater than 10 pphm was 1551 pphm hours.

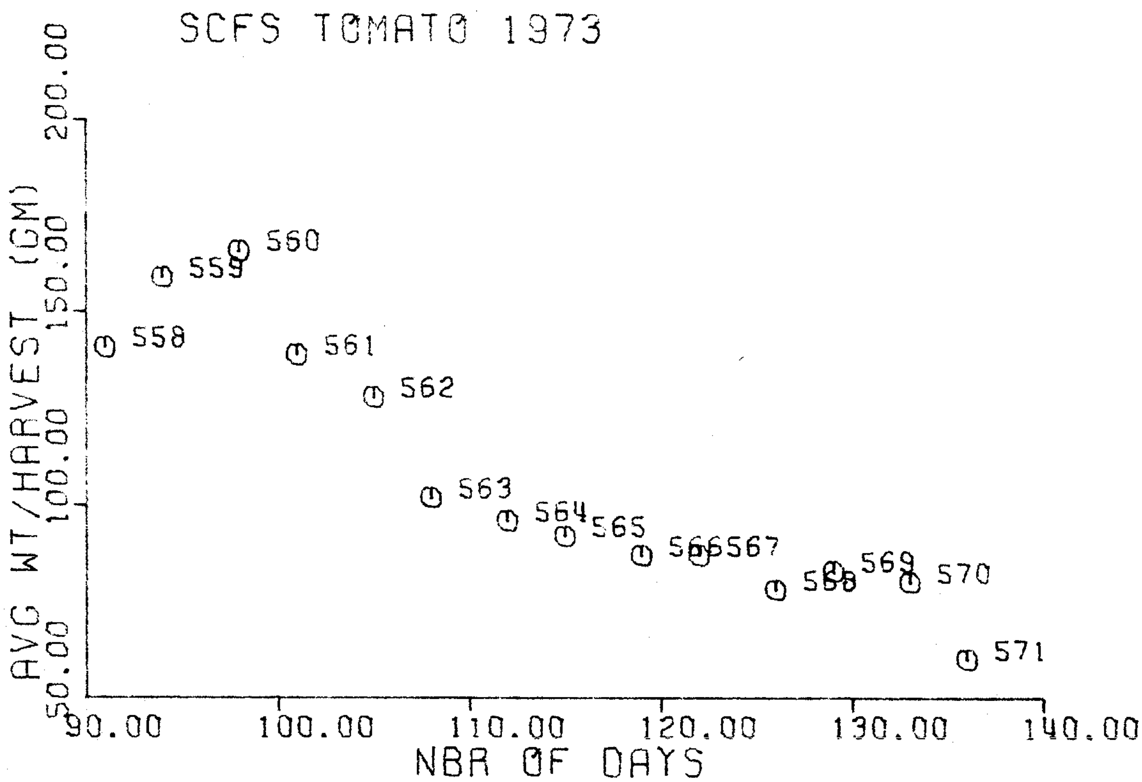


Figure 42. Plot of the average weight of H-11 tomato fruit per harvest (total wt./total number) at U.C.R. with time of harvest. The cumulative ozone dosage greater than 10 pphm was 7667 pphm hours.

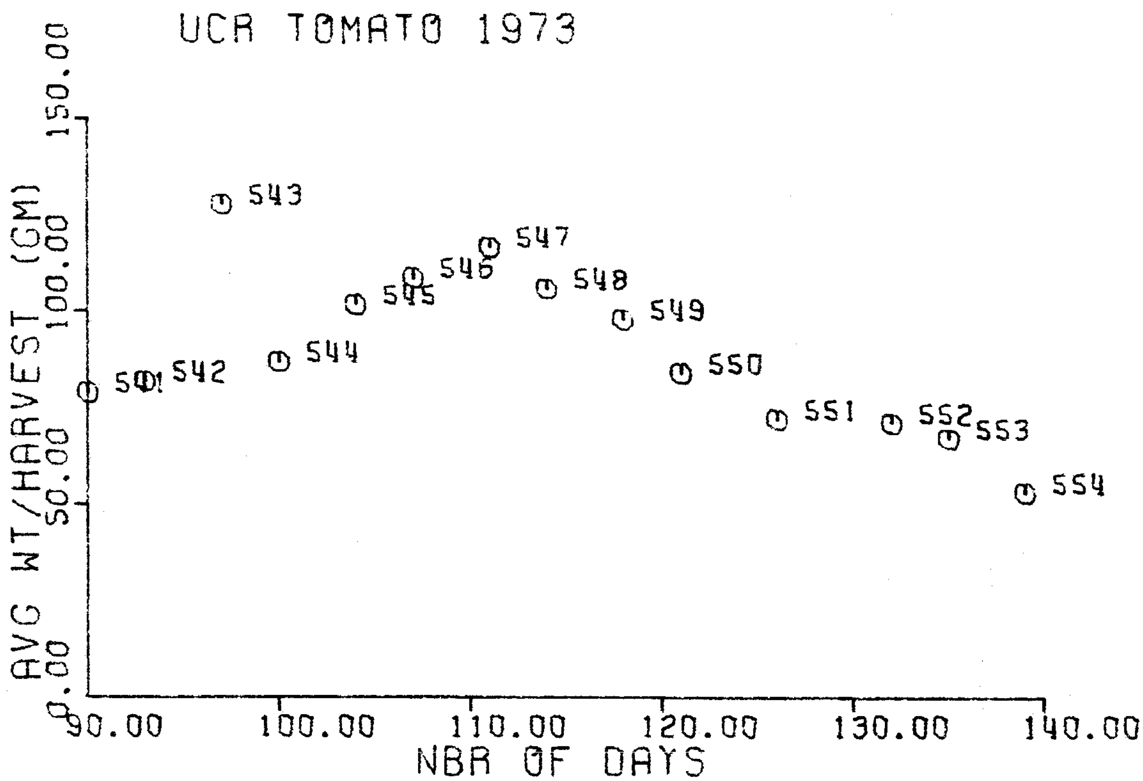


Figure 43. Correlation of weights of South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

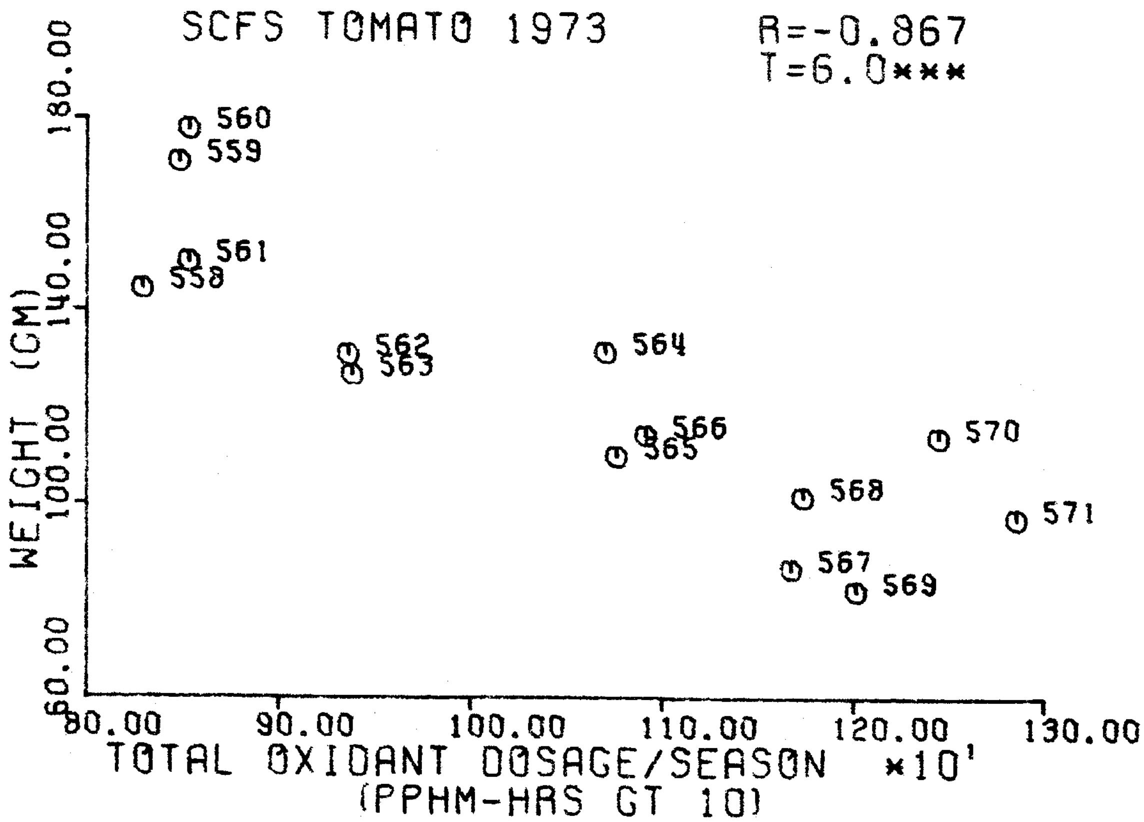


Figure 44. Correlation of percentage of irregularly-shaped fruit from South Coast Field Station tomato harvests with the total ambient oxidant dosage present during growth.

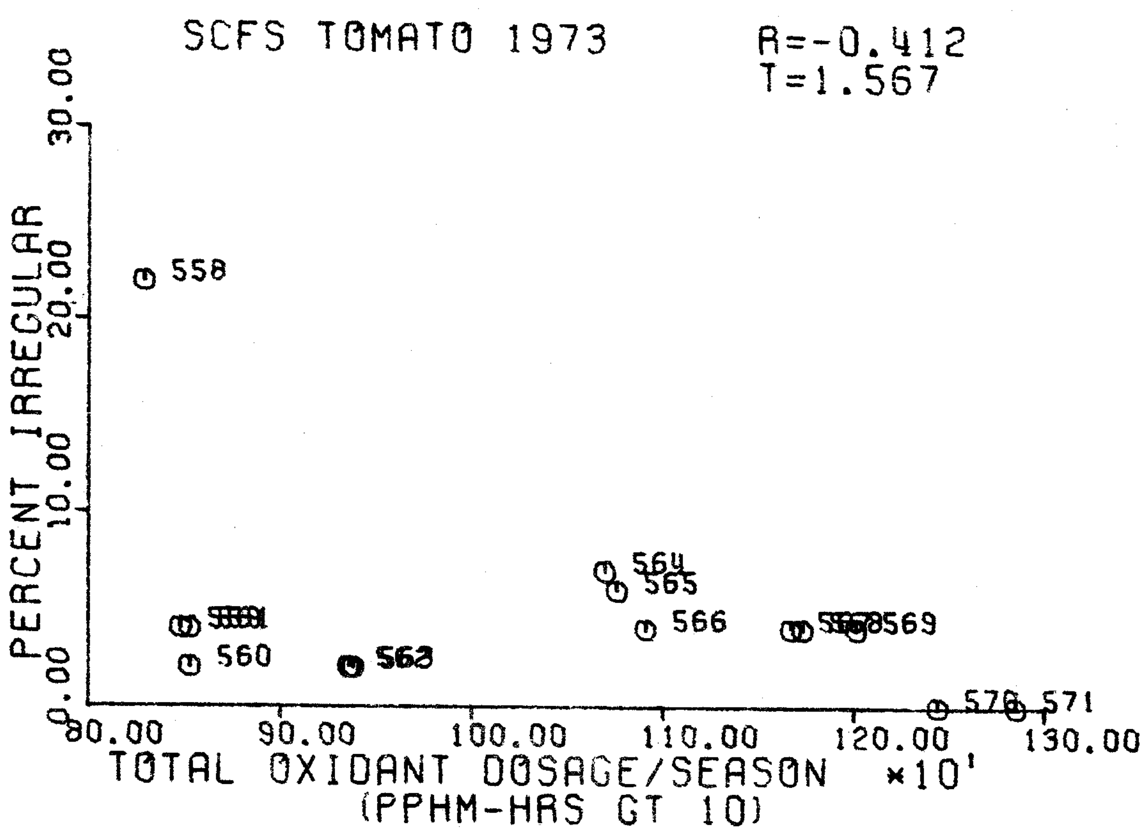


Figure 45. Correlation of weight of U.C.R. test plot H-11 tomato fruit with the total ambient oxidant dosage present during growth.

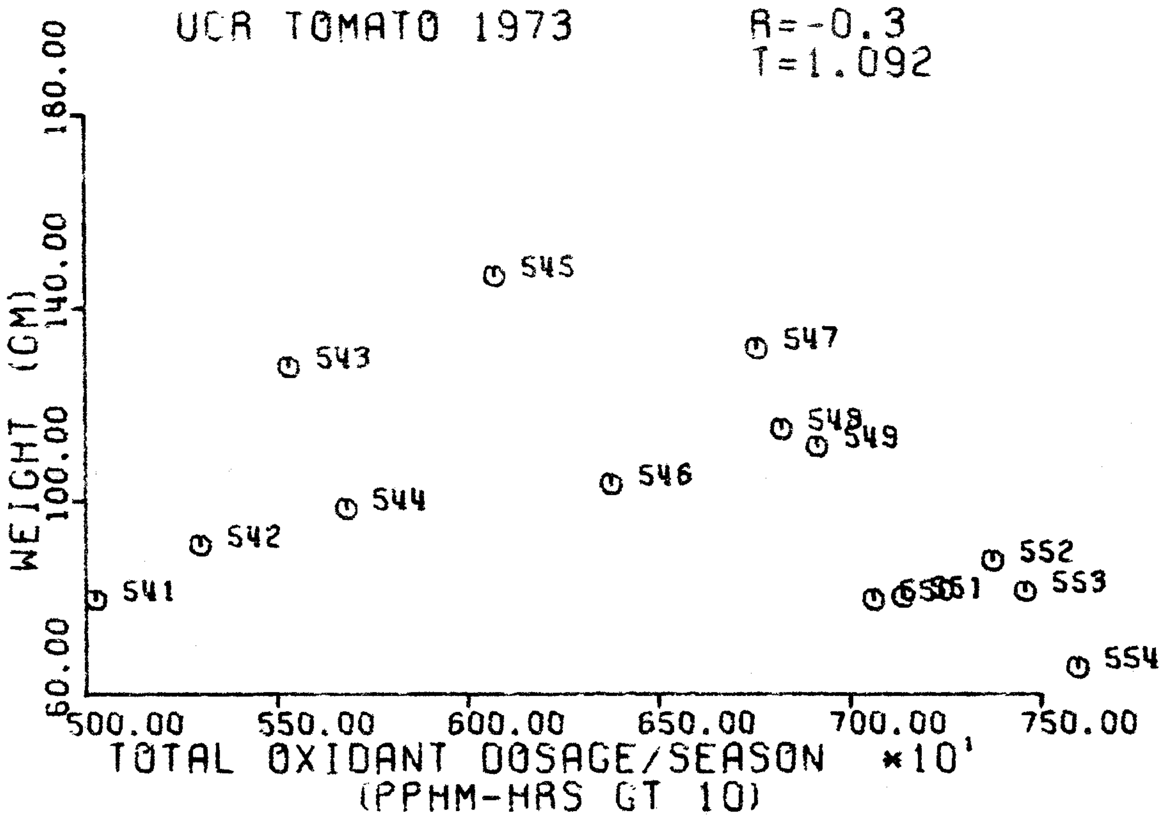


Figure 46. Correlation of percentage of irregularly-shaped fruit from U.C.R. test plot H-11 tomato harvests with the total ambient dosage present during growth.

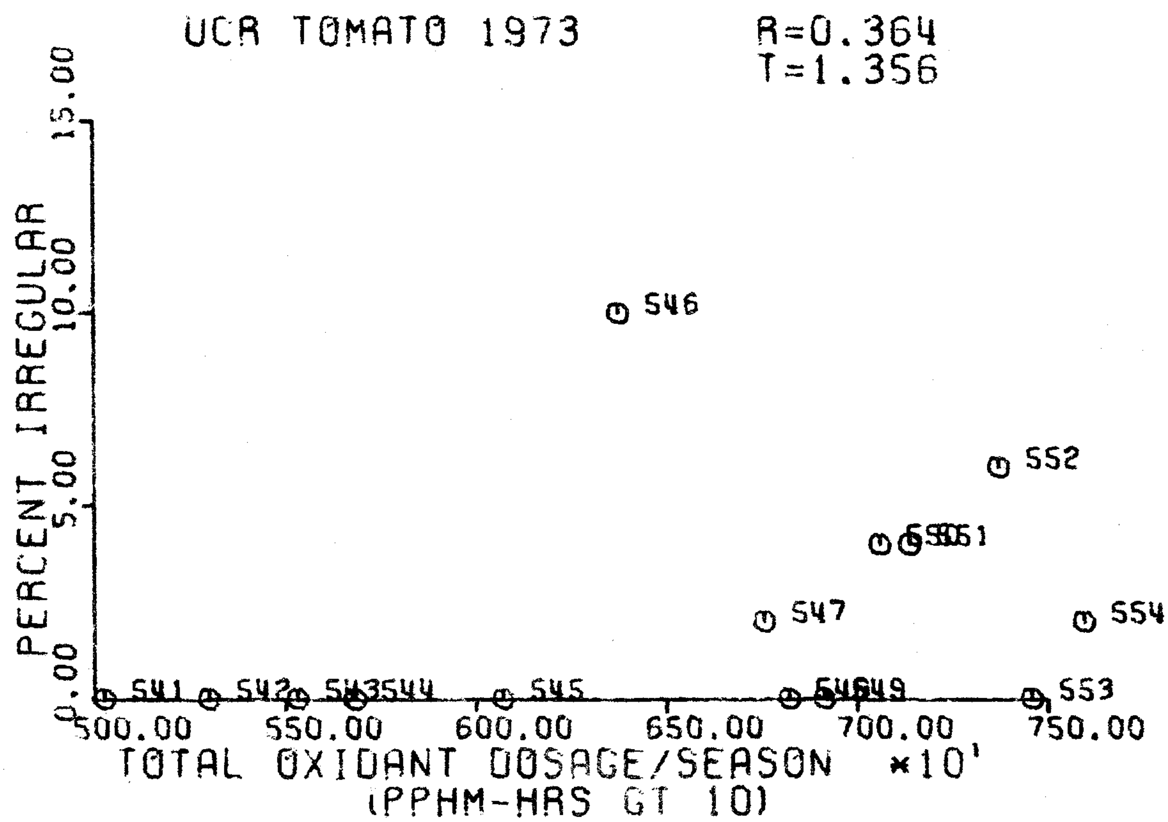


Figure 47. Correlation of the number of shoulder creases on South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

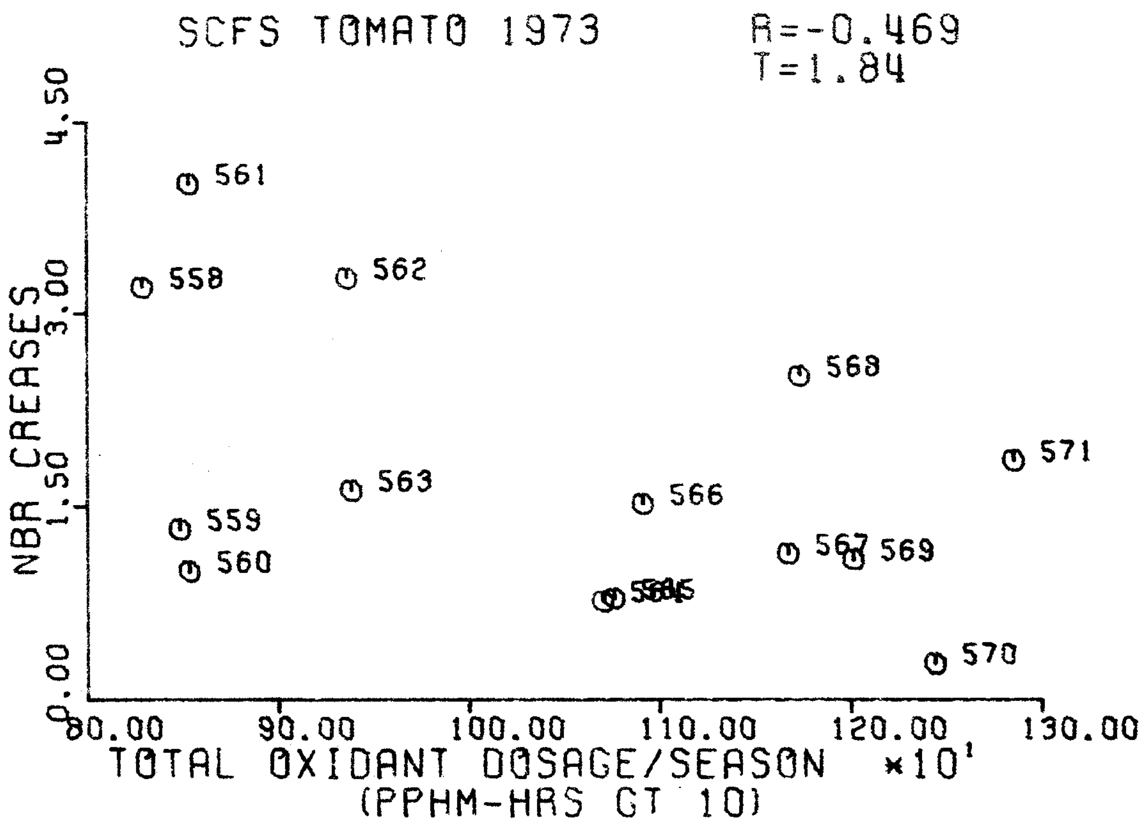


Figure 48. Correlation of the extent of shoulder creases on South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

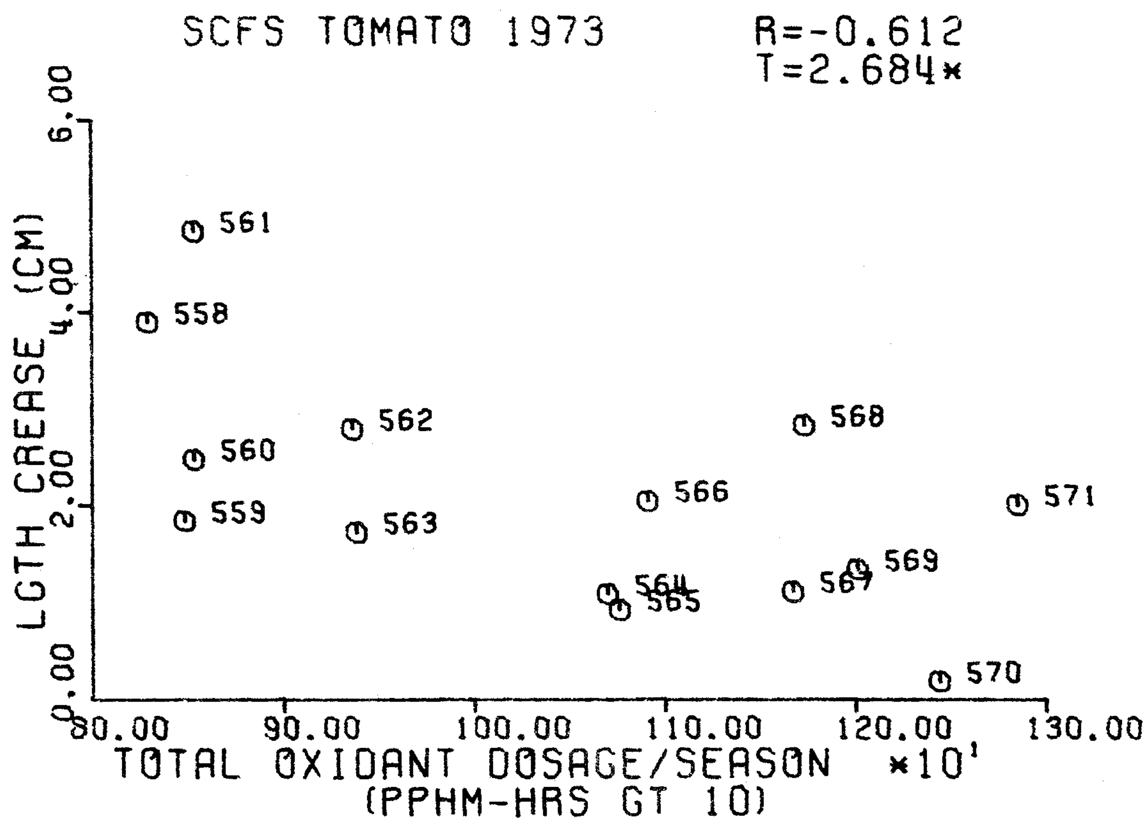


Figure 49. Correlation of the number of shoulder creases on U.C.R. test plot H-11 tomato fruit with the total ambient oxidant dosage present during growth.

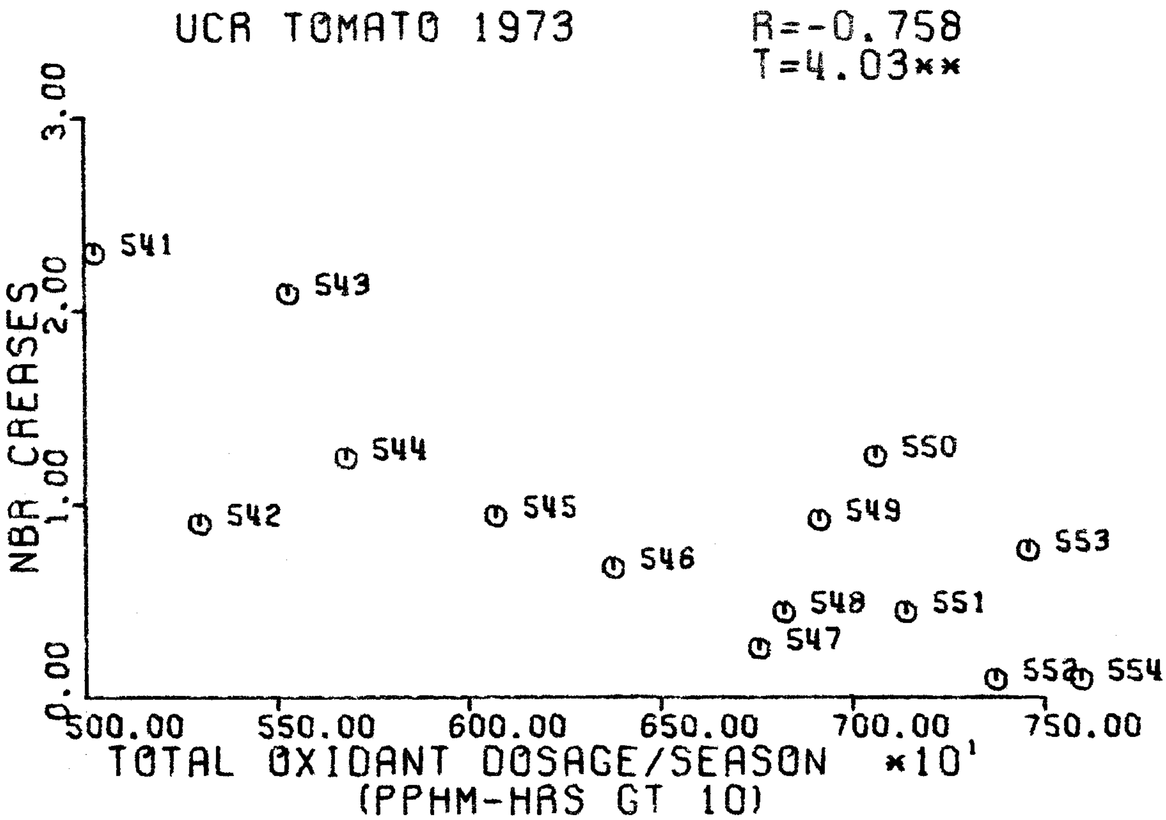


Figure 50. Correlation of the extent of shoulder creases on U.C.R. test plot H-11 tomato fruit with the total ambient dosage present during growth.

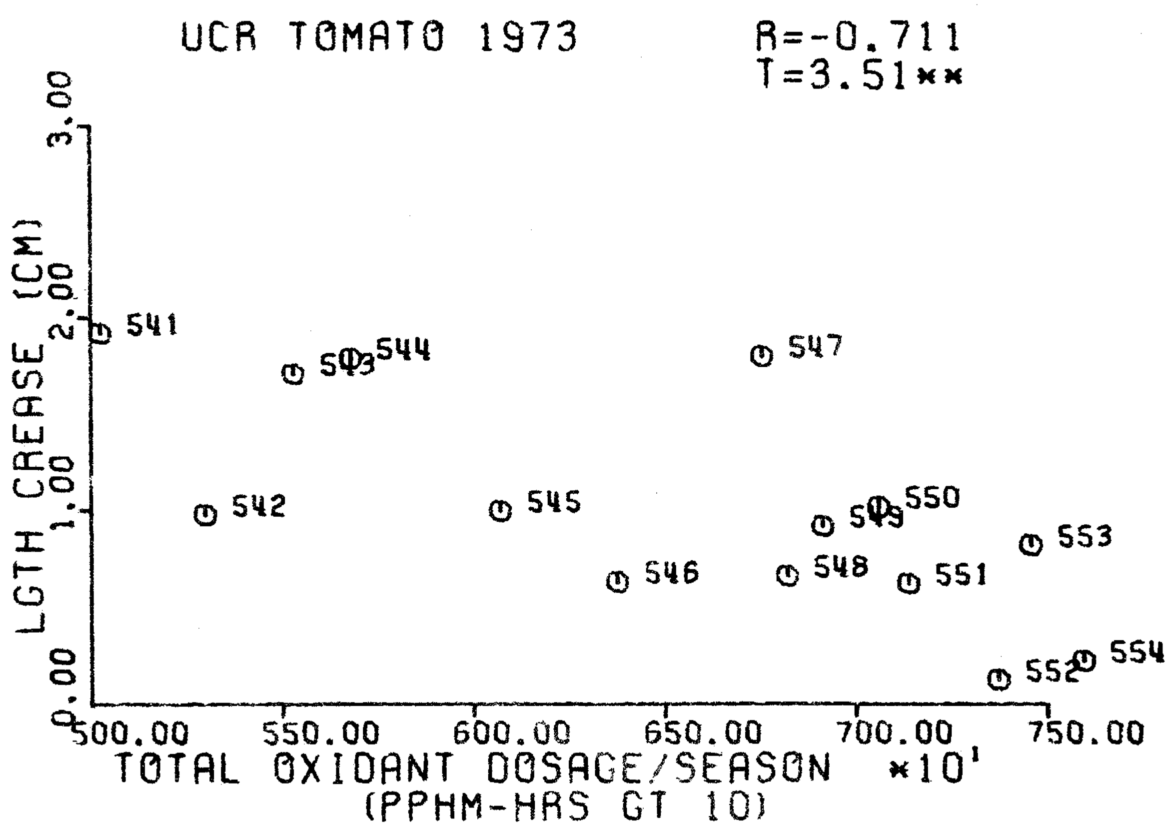


Figure 51. Correlation of heights of South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

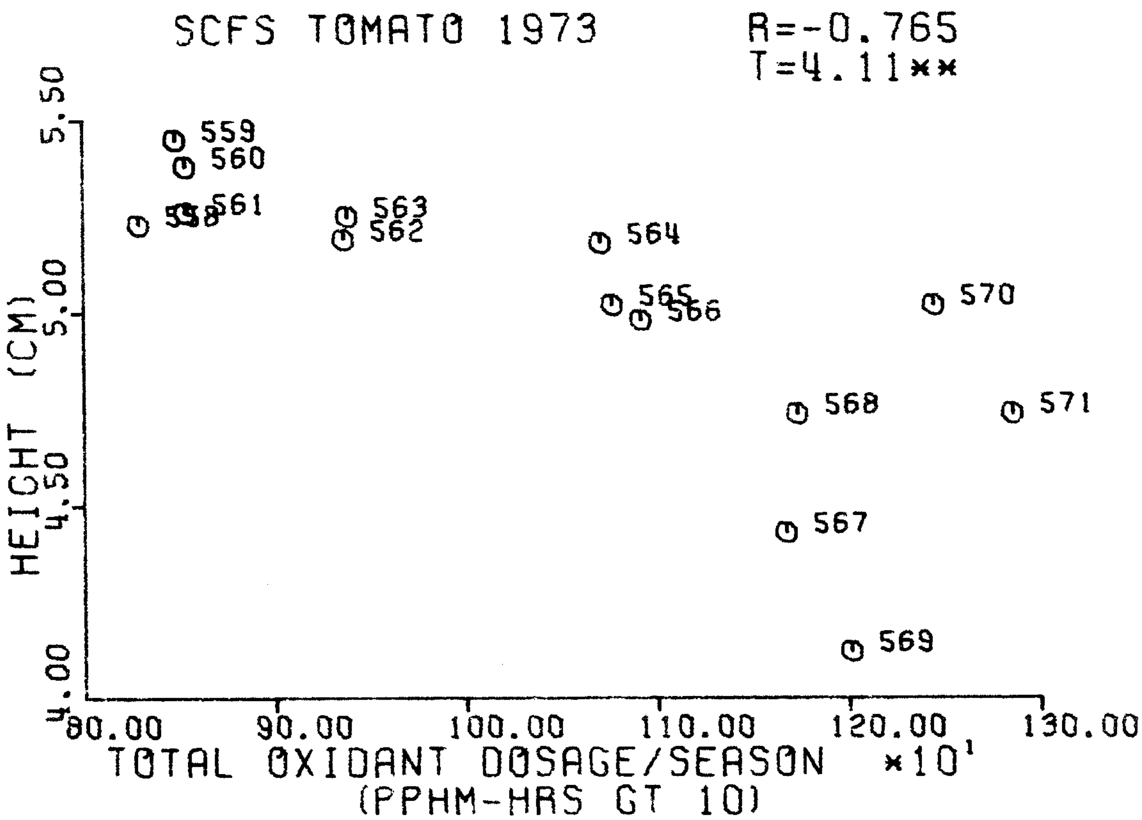


Figure 52. Correlation of diameters of South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

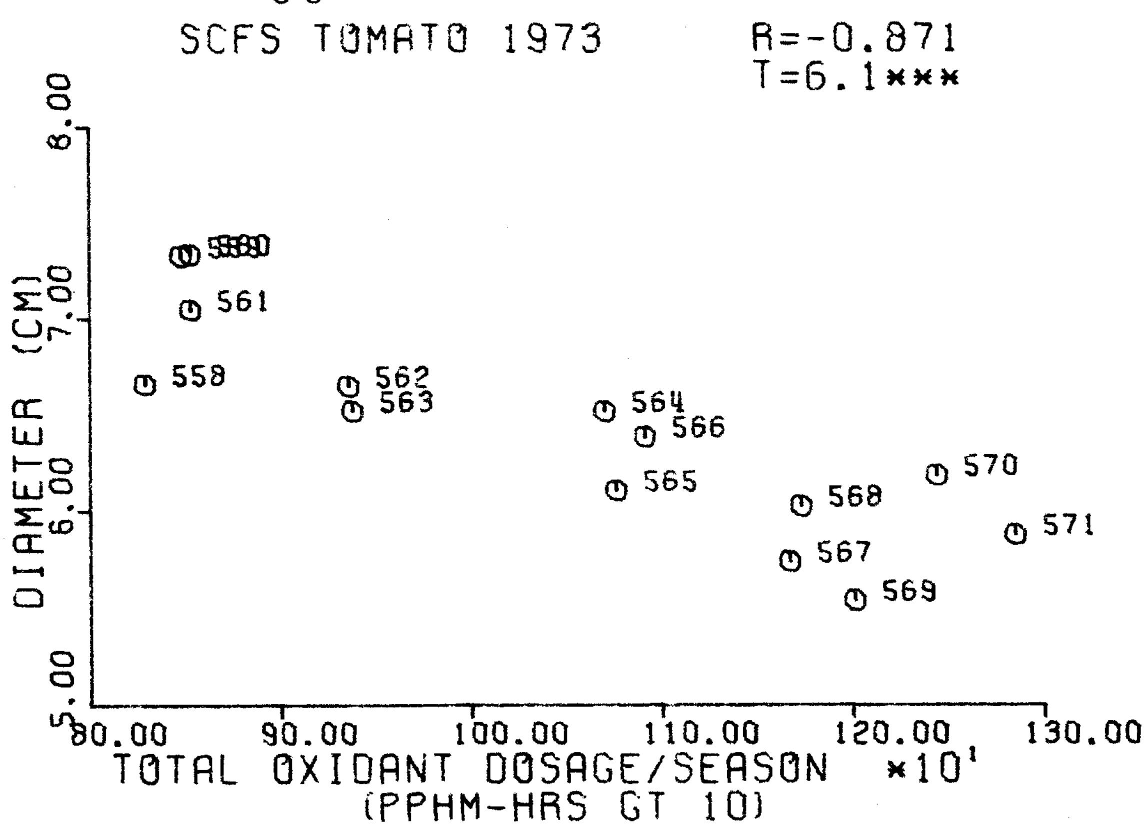


Figure 53. Correlation of heights of U.C.R. test plot H-11 tomato fruit with the total ambient dosage present during growth.

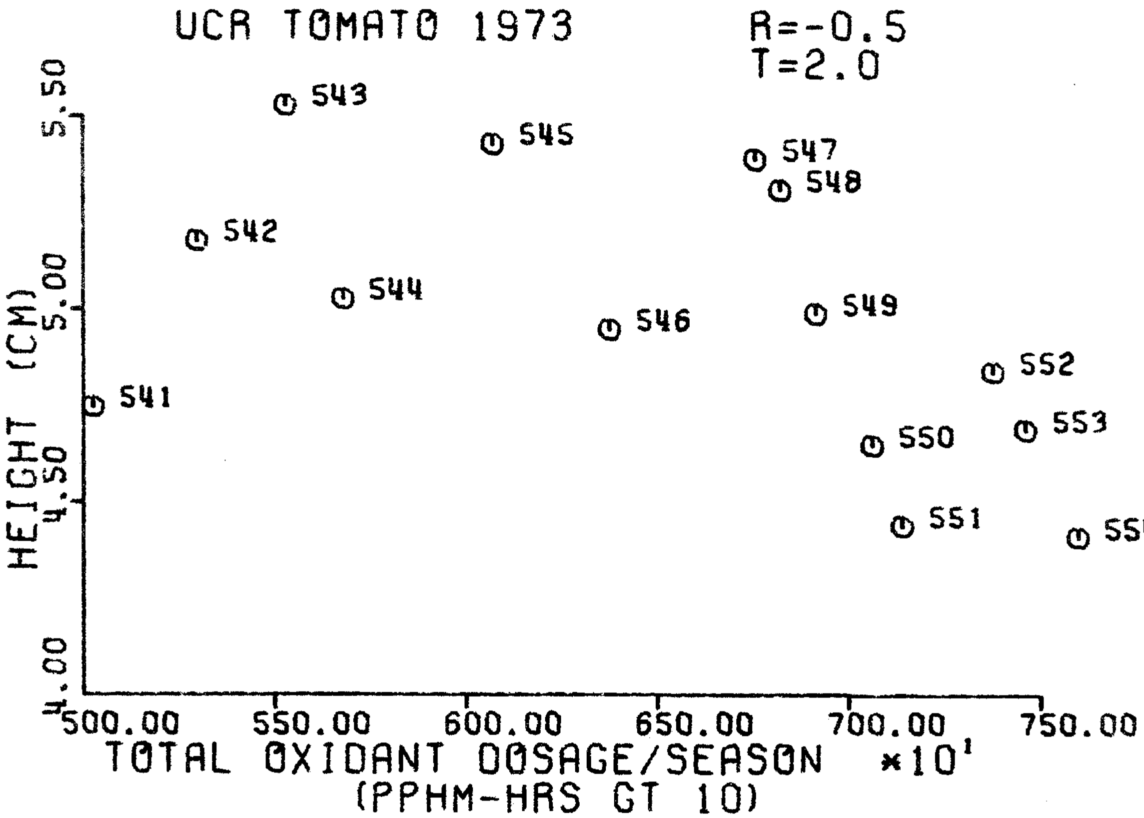


Figure 54. Correlation of diameters of U.C.R. test plot H-11 tomato fruit with the total ambient dosage present during growth.

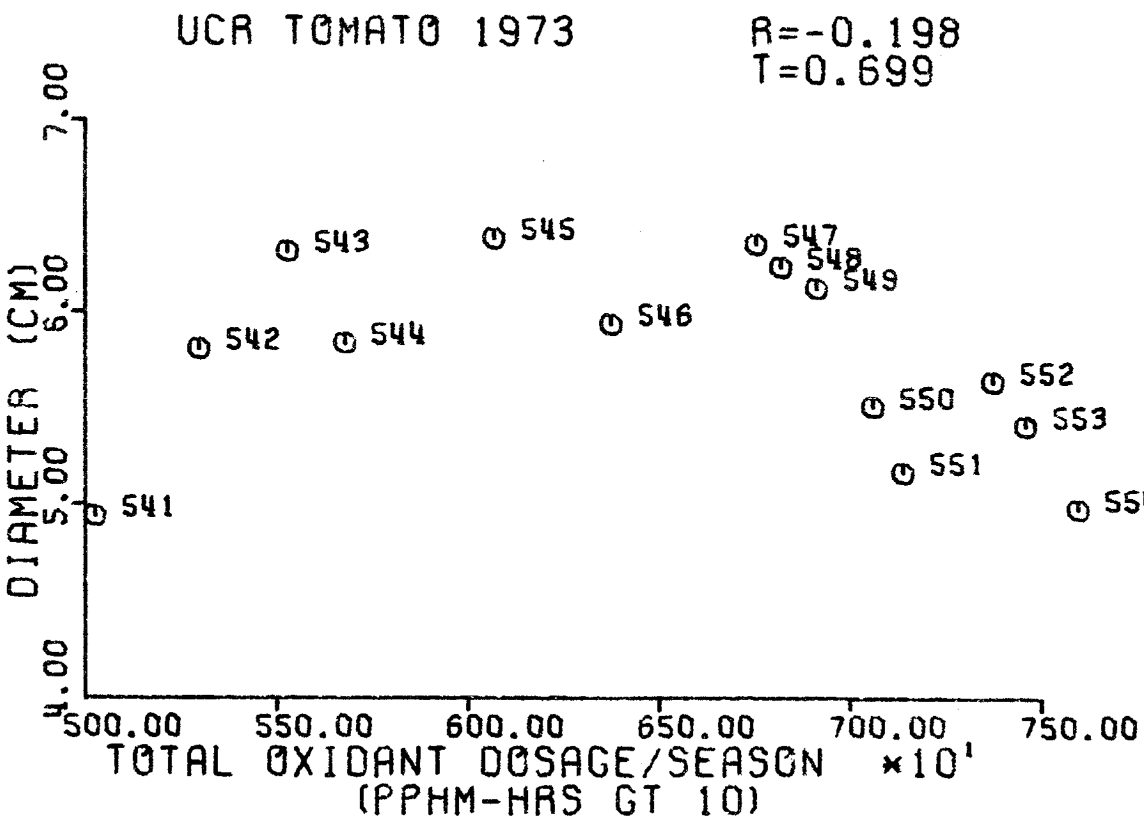


Figure 55. Correlation of the number of blemishes on South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

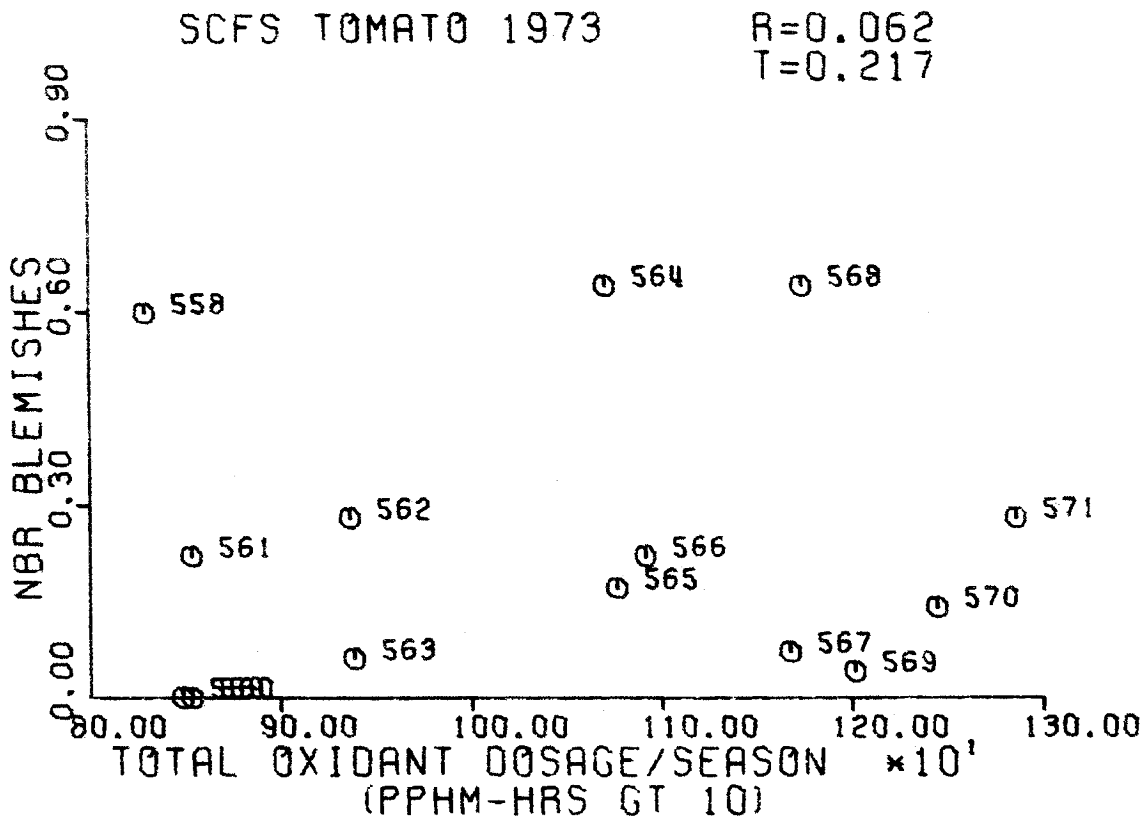


Figure 56. Correlation of the extent of blemishes on South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

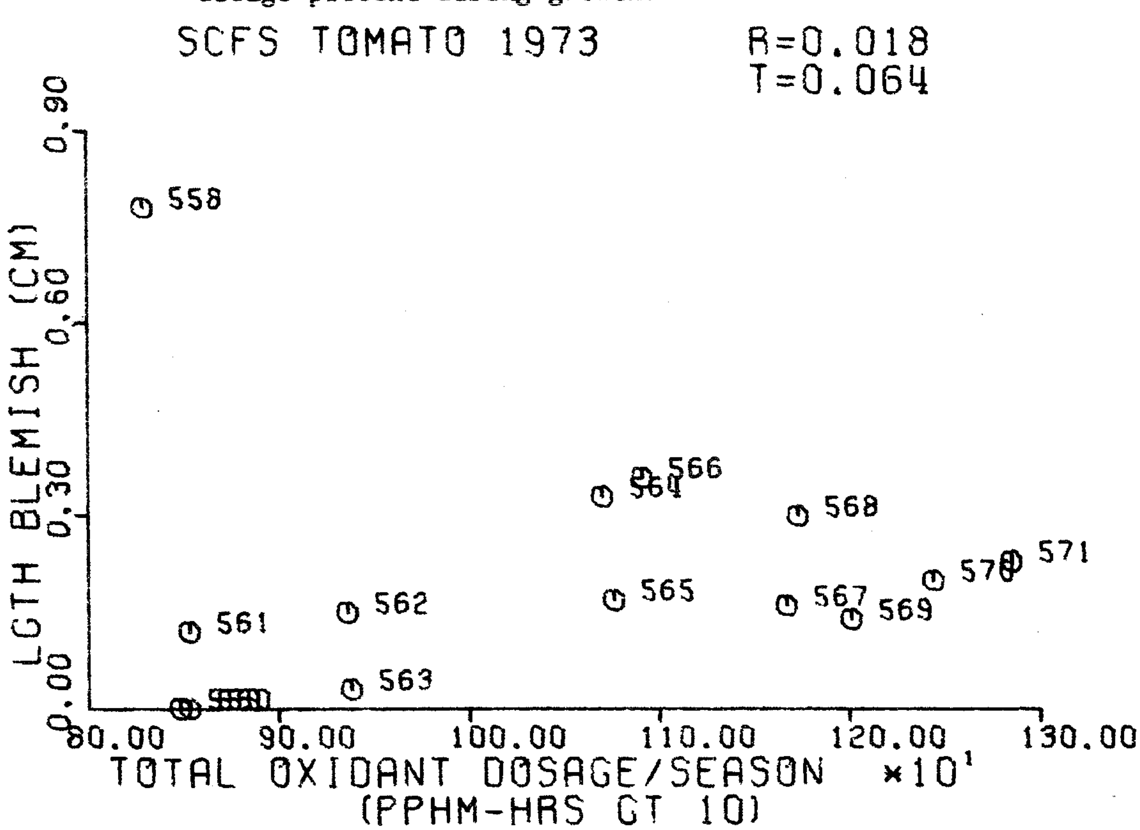


Figure 57. Correlation of the number of blemishes on U.C.R. test plot H-11 tomato fruit with the total ambient dosage present during growth.

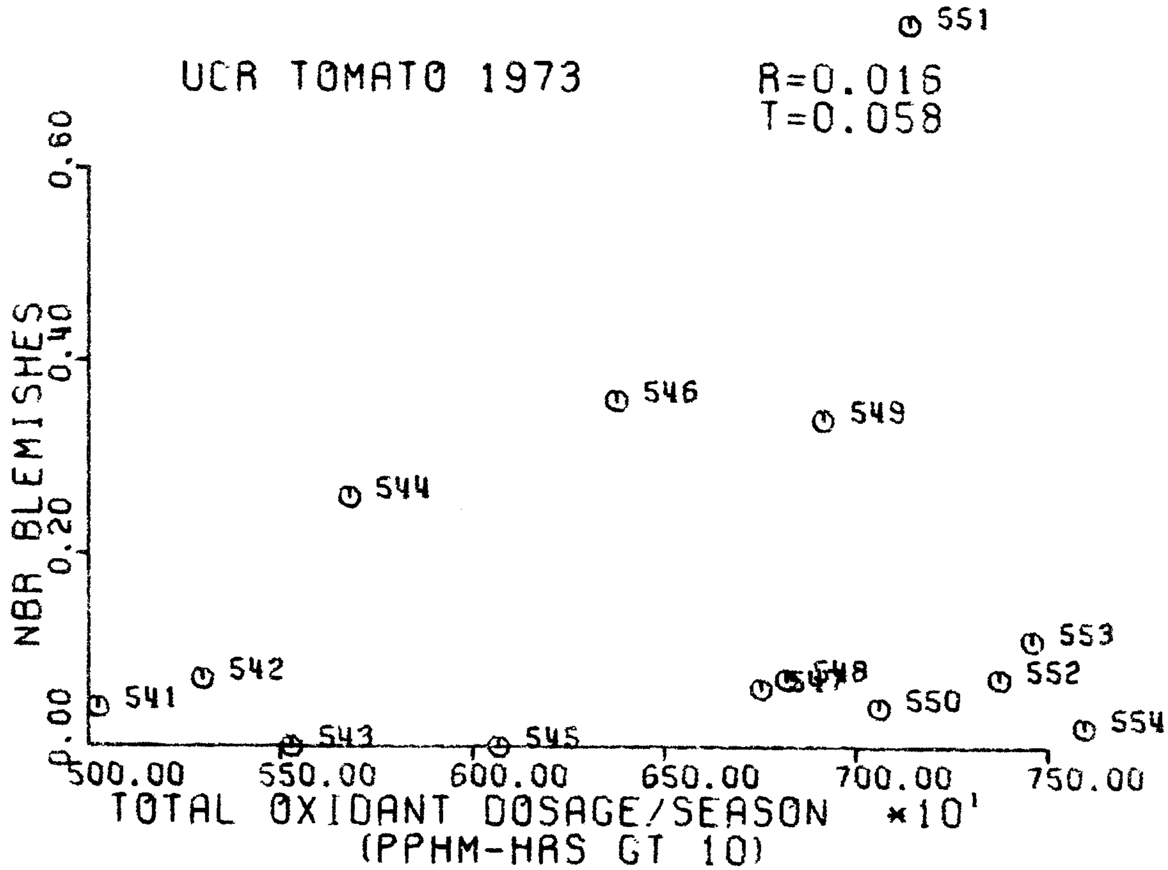


Figure 58. Correlation of the extent of blemishes on U.C.R. test plot H-11 tomato fruit with the total ambient dosage present during growth.

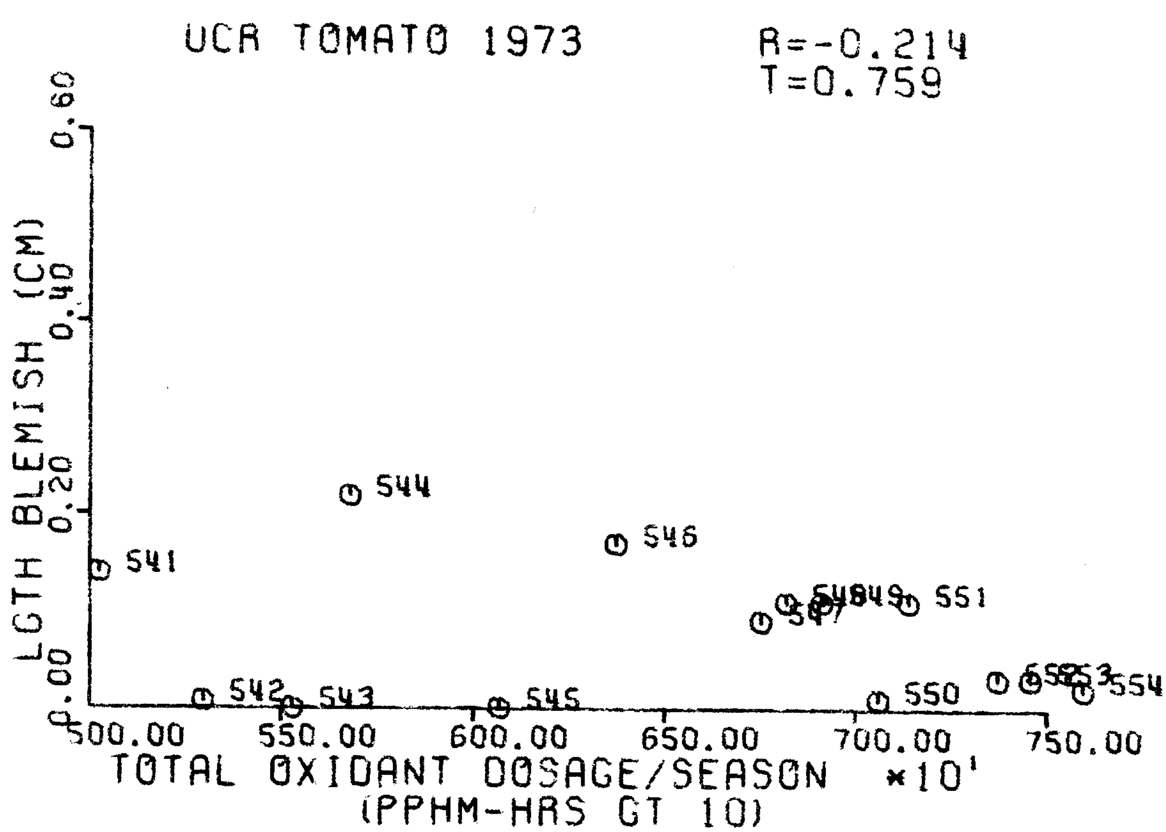


Figure 59. Correlation of the number of growth cracks on South Coast Field Station test plot H-11 tomato fruit with the total ambient oxidant dosage present during growth.

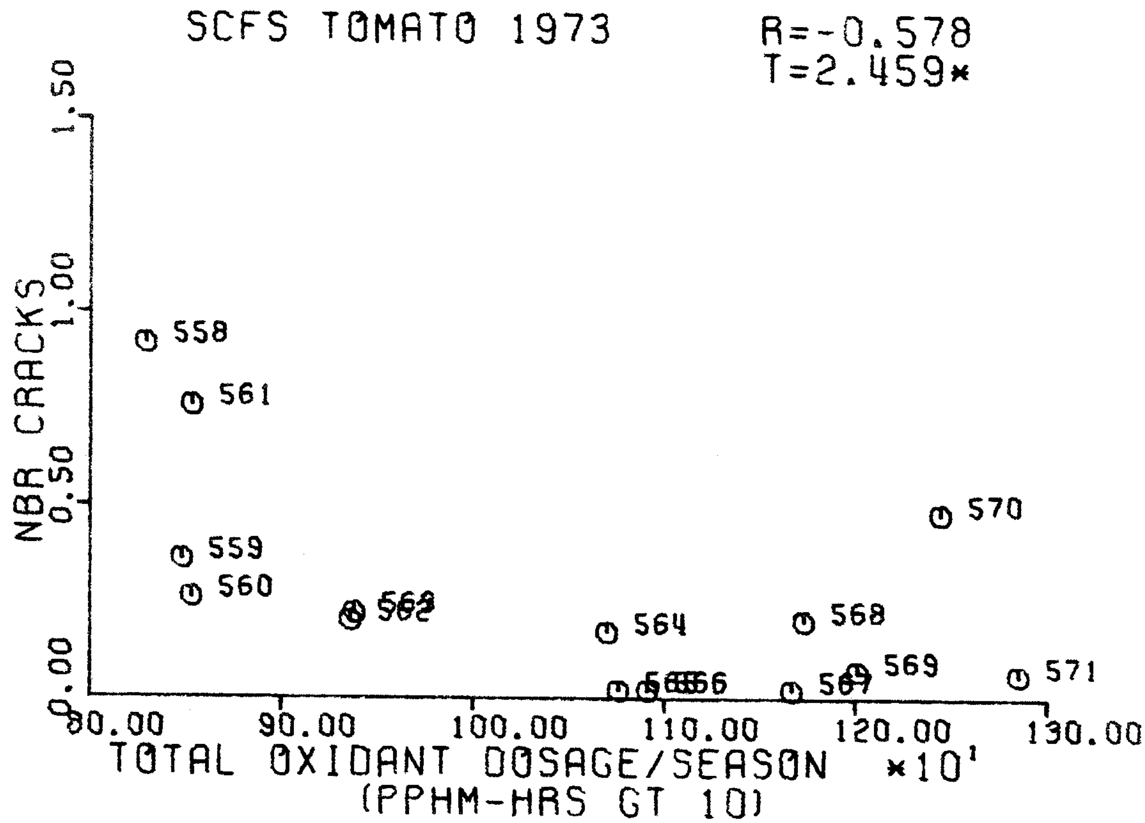


Figure 60. Correlation of the extent of growth cracks on South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

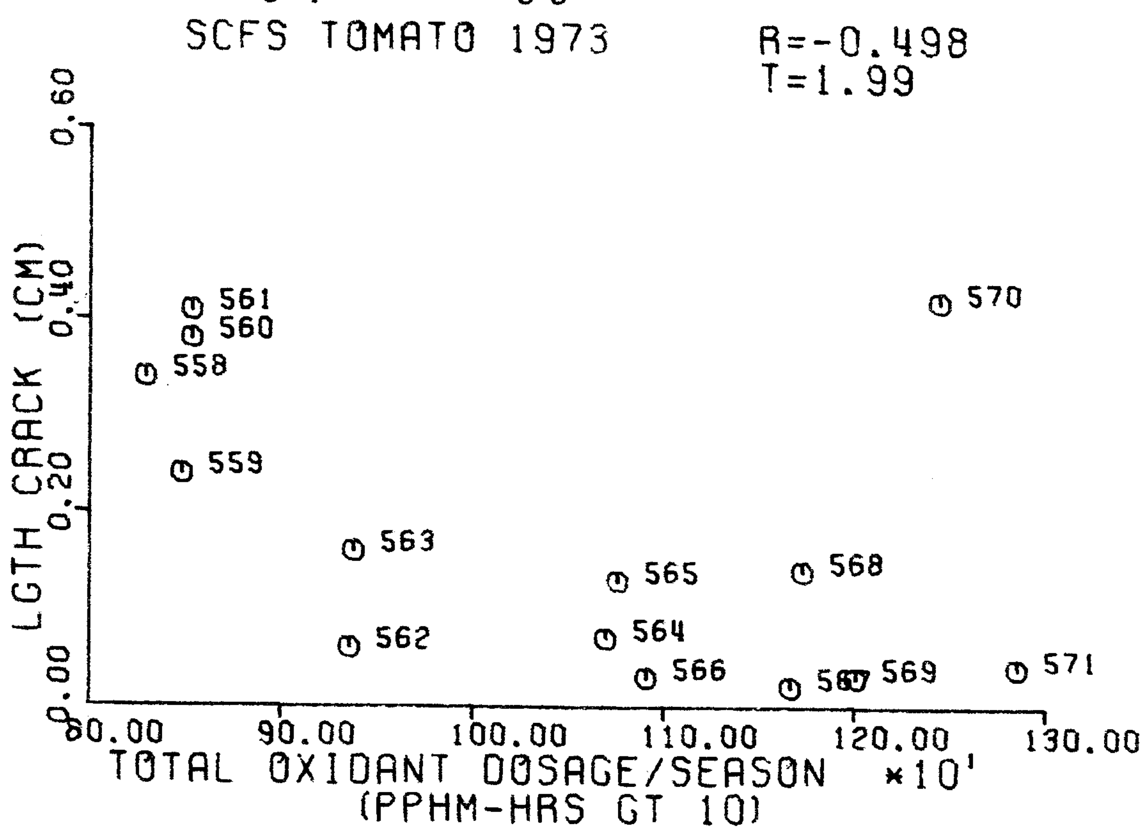


Figure 61. Correlation of the number of growth cracks on U.C.R. test plot H-11 tomato fruit with the total ambient oxidant dosage present during growth.

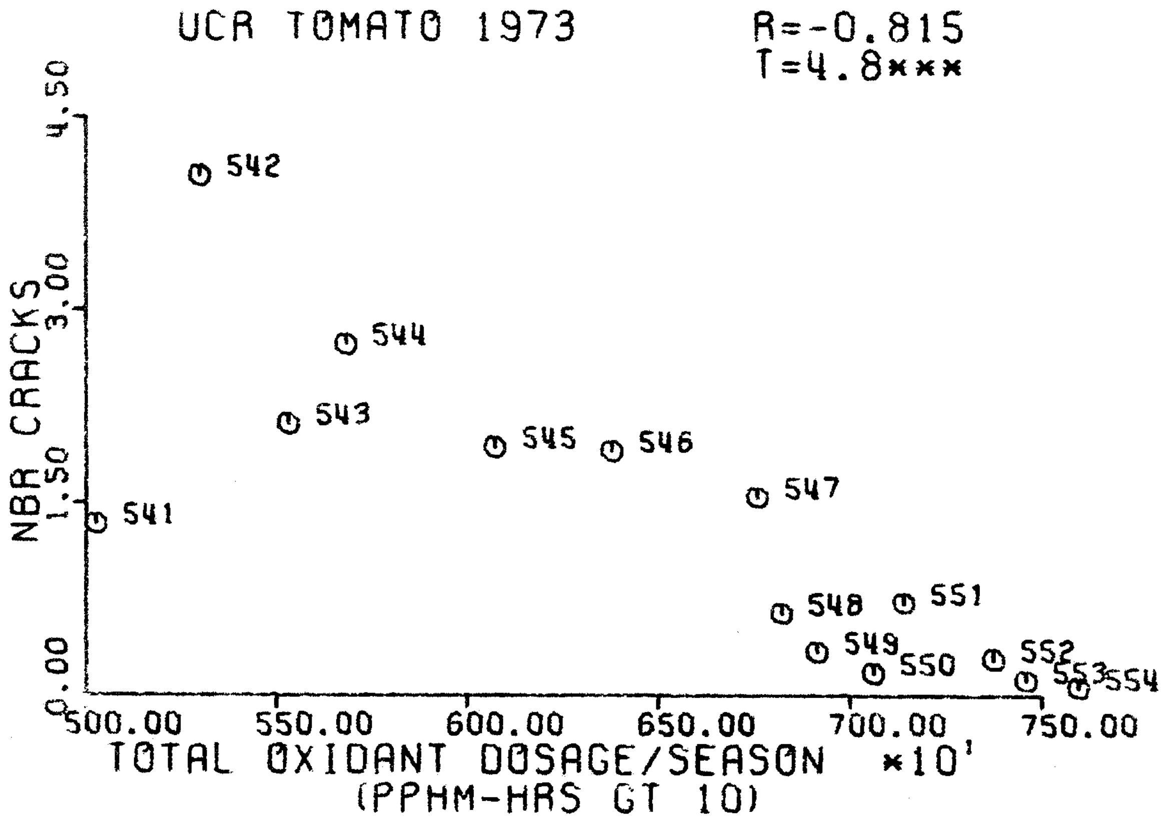


Figure 62. Correlation of the extent of growth cracks on U.C.R test plot H-11 tomato fruit with the total ambient oxidant dosage present during growth.

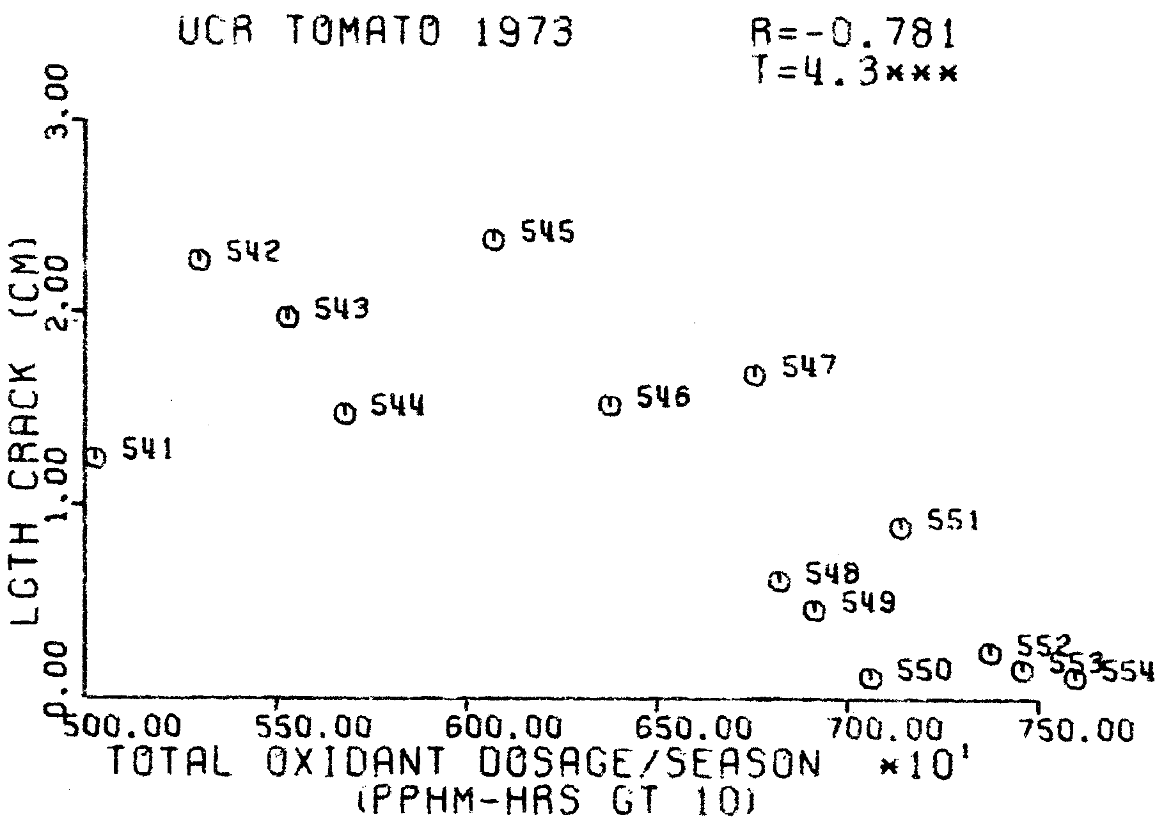


Figure 63. Correlation of the number of scars on South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

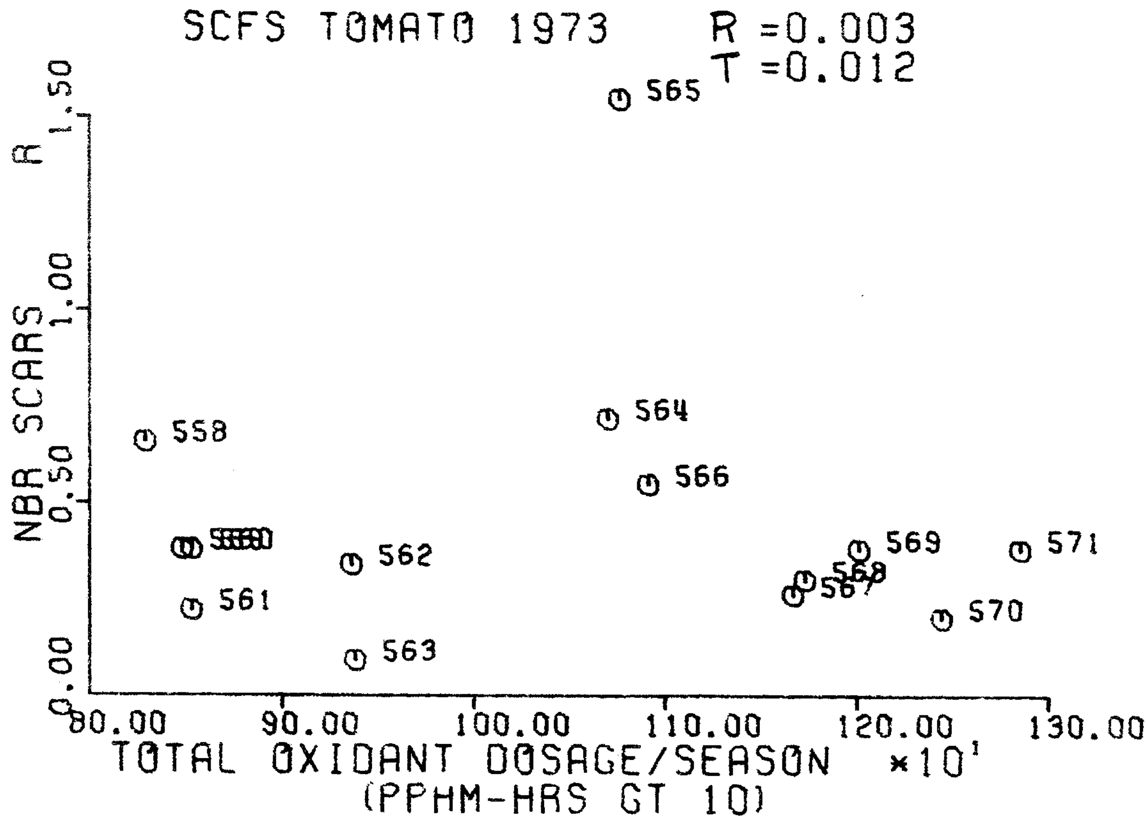


Figure 64. Correlation of the extent of scars on South Coast Field Station test plot H-11 tomato fruit with the total ambient dosage present during growth.

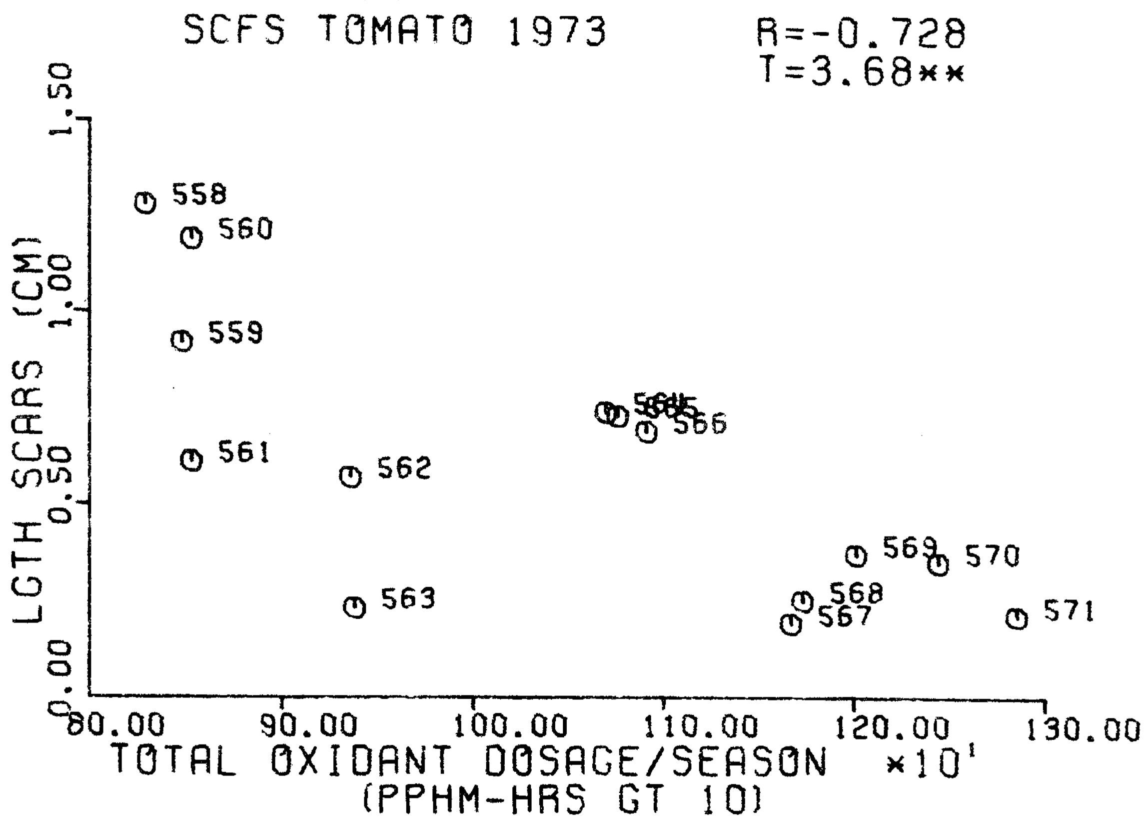


Figure 65. Correlation of the number of scars on U.C.R. test plot H-11 tomato fruit with the total ambient dosage present during growth.

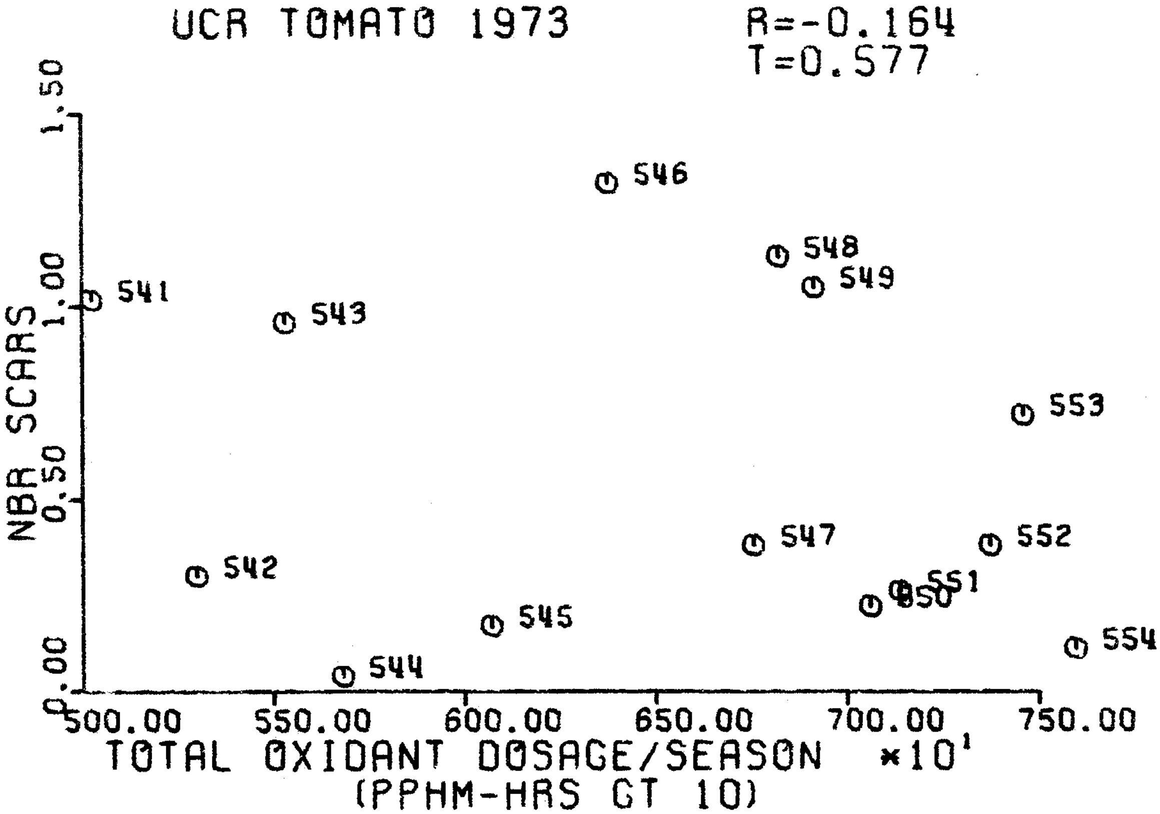
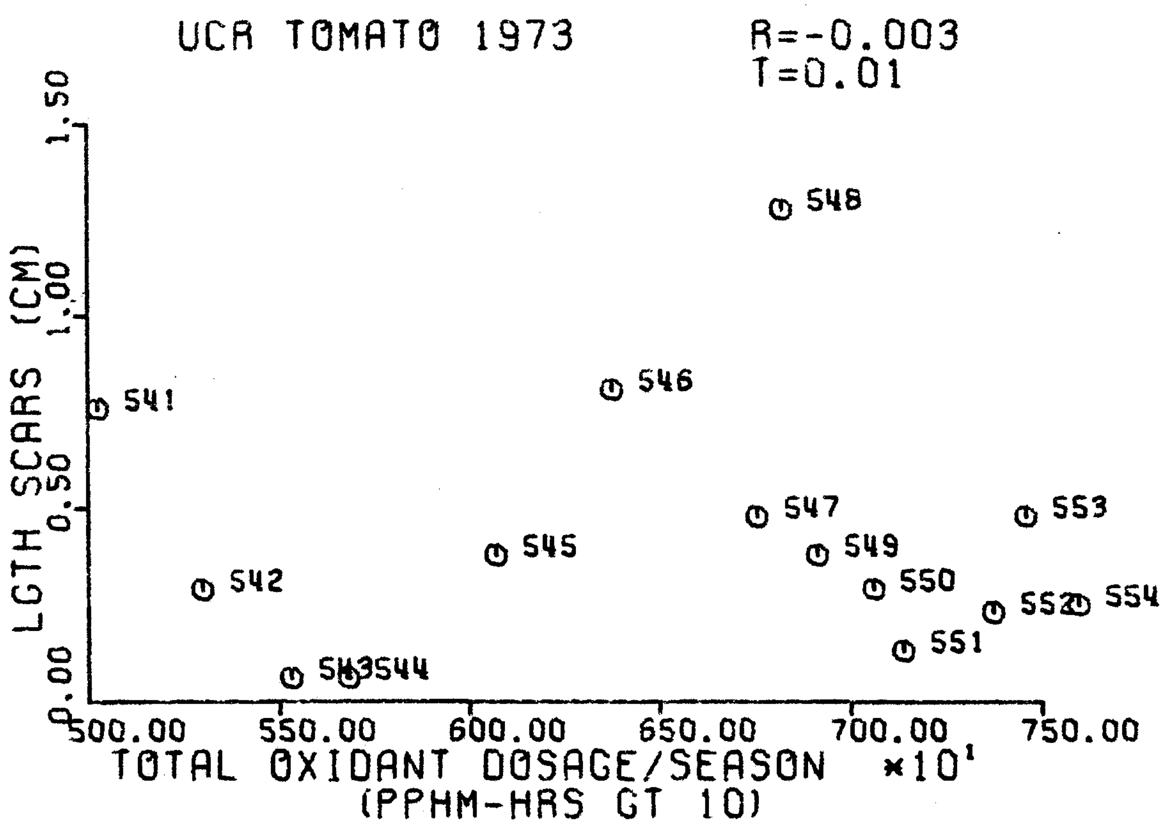


Figure 66. Correlation of the extent of scars on U.C.R. test plot H-11 tomato fruit with the total ambient dosage present during growth.



Introduction

Emperator #58 carrots were utilized for the yield phase of this program. Distribution of commercial growers was restricted to the western section of Riverside County as no large scale operations are present along the coastal plain or in San Bernardino and Los Angeles Counties.

Long-Term Ozone Fumigation

Treatments: 0 ppm ozone, .25 ppm ozone, .30 ppm ozone

Exposure: Treatments were exposed to the respective concentrations of fumigant 65 out of a total 1090 hours or about 6.0% of the growing period. Fumigations were about 6 hours in duration and at a frequency of 1.5 times a week.

Results: Summarized results are presented in Table 15. The phytotoxicity of ozone was demonstrated when the number of injured leaves per plant was compared among treatments. However, most physical measurements including length of root and number of leaves were not significantly different. Length of leaves was found to be greater in fumigated treatments.

Yield as measured by fresh and dry weights of roots was observed to be considerably reduced in fumigated treatment plants. Total fresh and dry weights of plants also exhibited reductions but were probable reflections of the included root weights.

Nutritional Analyses of 1972 Fumigation Studies (7)

All analyses were run with standard procedures utilized by the staff of the Western Regional Laboratory, United States Department of Agriculture, Berkeley, California.

I. PAN Fumigated Emperator #58 Carrots

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Results: PAN appeared to cause a significant reduction in vitamin A content in harvested carrot roots (Table 16). The 40 ppb treatment roots were found to contain 76% less vitamin A when compared to the control treatment roots. Other nutritional compounds within fumigated carrot roots were not significantly lower than the control roots or differences did not correlate with concentration.

II. Ozone Fumigated Emperator #58 Carrots

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Results: Roots from the .35 ppm treatment plants were observed to have a significantly reduced solids content and a correspondingly greater amount of water (Table 17). The reduction in solids was not apparent in protein or other nutrient levels but an insufficient amount of samples prevented analysis for carbohydrates. Niacin levels were elevated in the roots of both ozone fumigated treatments. The levels of copper and zinc within the roots of the fumigated treatments were significantly lower than the control.

Field Study

Commercial carrot growing operations made valid yield comparisons between field plots nearly impossible. No standardization of seeding rates existed among growers or even among fields of the same grower. Seed was applied at an arbitrary rate set from experience and no two fields were seeded at the same rate.

The South Coast Field Station test plot was found to be infested with bacterial root rot and abandoned.

Locations: Three commercial field plots and two test plots of Emperator #58 carrots were harvested (Map 7).

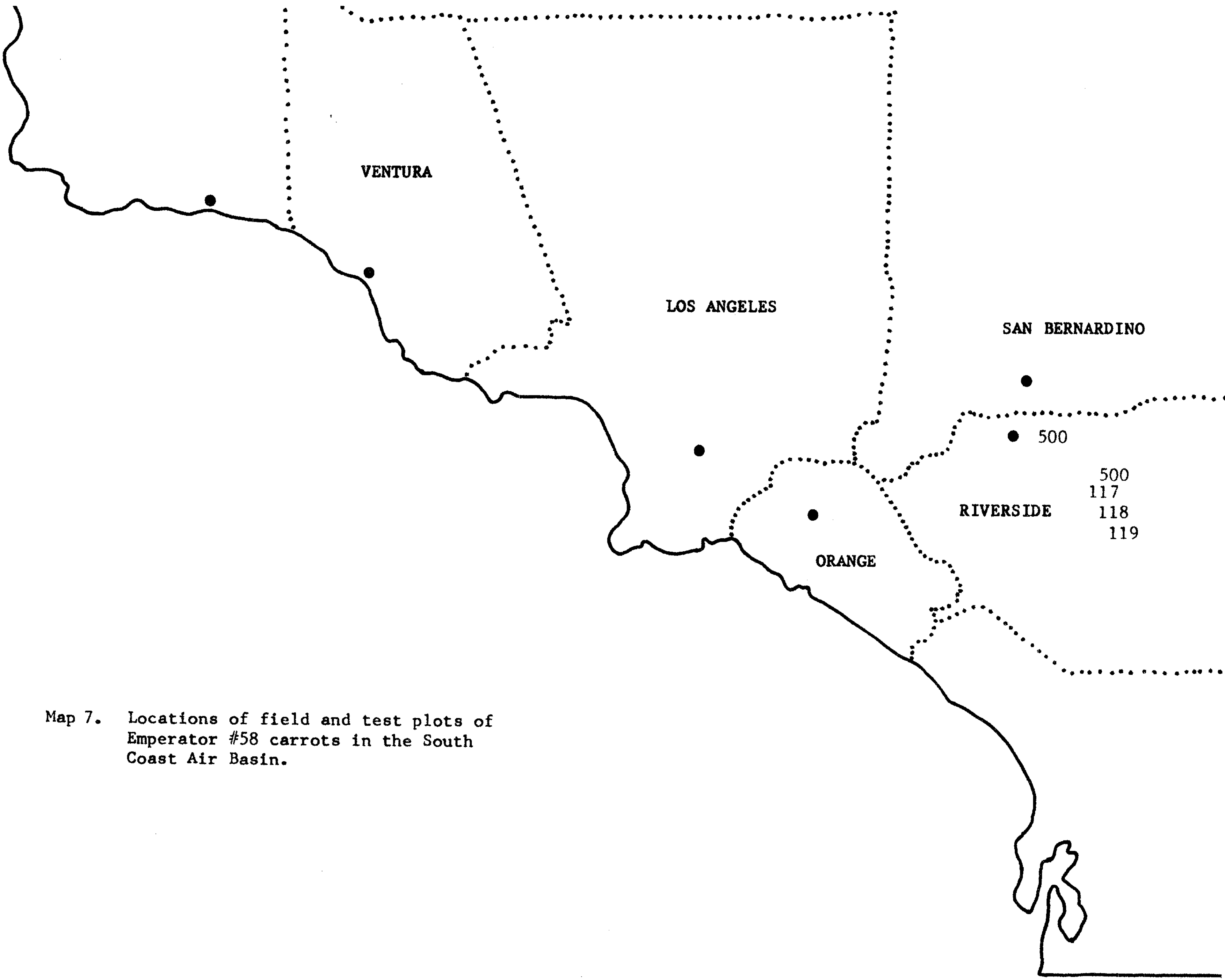
Sampling Techniques: Sixteen one-foot plots per field were staked out at emergence. All carrots within the plots were harvested and 150 individuals were selected at random and analyzed. All harvested samples were of a uniform age and of harvestable size.

Results: No measured carrot parameter was significantly associated with ozone dosage in the linear correlations (Figures 67 - 74). Ozone injury was visible on the leaves of many plants in most locations but possible yield reductions were not distinguishable from the effects of crowding and competition and were subsequently proven to be statistically insignificant.

Discussion

Ozone fumigation results clearly show a significant decrease in root weight associated with high concentration ozone exposures. This work was observed on replicates of individual plants grown in containers. Commercial field grown plants are seeded in various densities introducing the important variables of crowding and competition. These factors are known to have an enormous influence on plant size and yield and effectively mask other influences. An effective yield study would require standardization of grower seeding rates, an impossibility on a large scale with the variety of equipment and practices being utilized by the various growers. Field plots seeded and maintained by program personnel could determine the effect of ozone on the variety in general, but its applicability to commercial fields would not be valid unless spacing and the effects of competition could be included.

The oxidants PAN and ozone appear to have different effects on the composition of root materials. PAN appears to reduce the vitamin A content in roots while ozone reduces the solid content, probably in the form carbohydrates.



Map 7. Locations of field and test plots of Emperator #58 carrots in the South Coast Air Basin.

Table 15. Summary of significant ozone effects on Emperator #58 carrots as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Length Root	No. Leaves	Length Leaves	No. Injured Leaves
Ozone	0	- a[1]	- a	- a A[2]	- a A
Treatments	.25	- a	- a	-9.85[3] ab A	-883.33 b B
(ppm)	.30	- a	- a	-14.76 b A	-1585.19 c B

		No. Lateral Roots	Fresh Wt. Root	Fresh Wt. Leaves
Ozone	0	- a	- a A	- a
Treatments	.25	- a	36.66 b B	- a
(ppm)	.30	- a	47.53 b B	- a

		Dry Wt. Root	Dry Wt. Leaves	Total Fresh Wt.	Total Dry Wt.
Ozone	0	- a A	- a	- a A	- a A
Treatments	.25	32.13 b B	- a	22.39 b B	12.13 a AB
(ppm)	.30	46.01 b B	- a	30.36 b B	26.84 b B

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 16. Summary of the effects of PAN on nutritional constituents in Emperator #58 carrot roots as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Solids	Water	Nitrogen	Protein
PAN	0	- a[1] A[2]	- a A	- a A	- a A
Treatments	20	-14.8[3] b B	1.97 b B	-20.34 b A	-20.46 b A
(ppb)	40	-0.5 a A	0.07 a A	-11.86 ab A	-11.92 ab A

		Fiber	Ash	Carbohydrate	Calories
PAN	0	- a A	- a	- a A	- a A
Treatments	20	-14.52 b B	- a	-15.86 b A	-16.12 b B
(ppb)	40	-2.25 a AB	- a	0.77 a A	-0.83 a A

		Vitamin A	Vitamin C	Thiochrome	Riboflavin
PAN	0	- a A	- a	- a	- a
Treatments	20	26.81 a AB	- a	- a	- a
(ppb)	40	76.02 b B	- a	- a	- a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 17. Summary of the effects of ozone on nutritional constituents in Emperator #58 carrots as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Protein	Nitrogen	Niacin	Solids	Thiochrome
Ozone	0	- a[1]	- a	- a A	- a A[2]	- a
Treatments	.20	- a	- a	-41.3[3] b B	-1.15 a A	- a
(ppm)	.35	- a	- a	-31.98 b B	15.67 b B	- a

		Riboflavin	Vitamin A	Vitamin C	Water
Ozone	0	- a	- a	- a	- a A
Treatments	.20	- a	- a	- a	0.19 a A
(ppm)	.35	- a	- a	- a	-2.65 b B

		Mn	Fe	Cu	Zn	Sr
Ozone	0	- a	- a	- a A	- a A	- a
Treatments	.20	- a	- a	25.0 b AB	29.41 b A	- a
(ppm)	.35	- a	- a	39.72 a B	32.35 b A	- a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Figure 67. Correlation of lengths of harvested Emperator #58 carrot roots with the total ambient dosage present during growth.

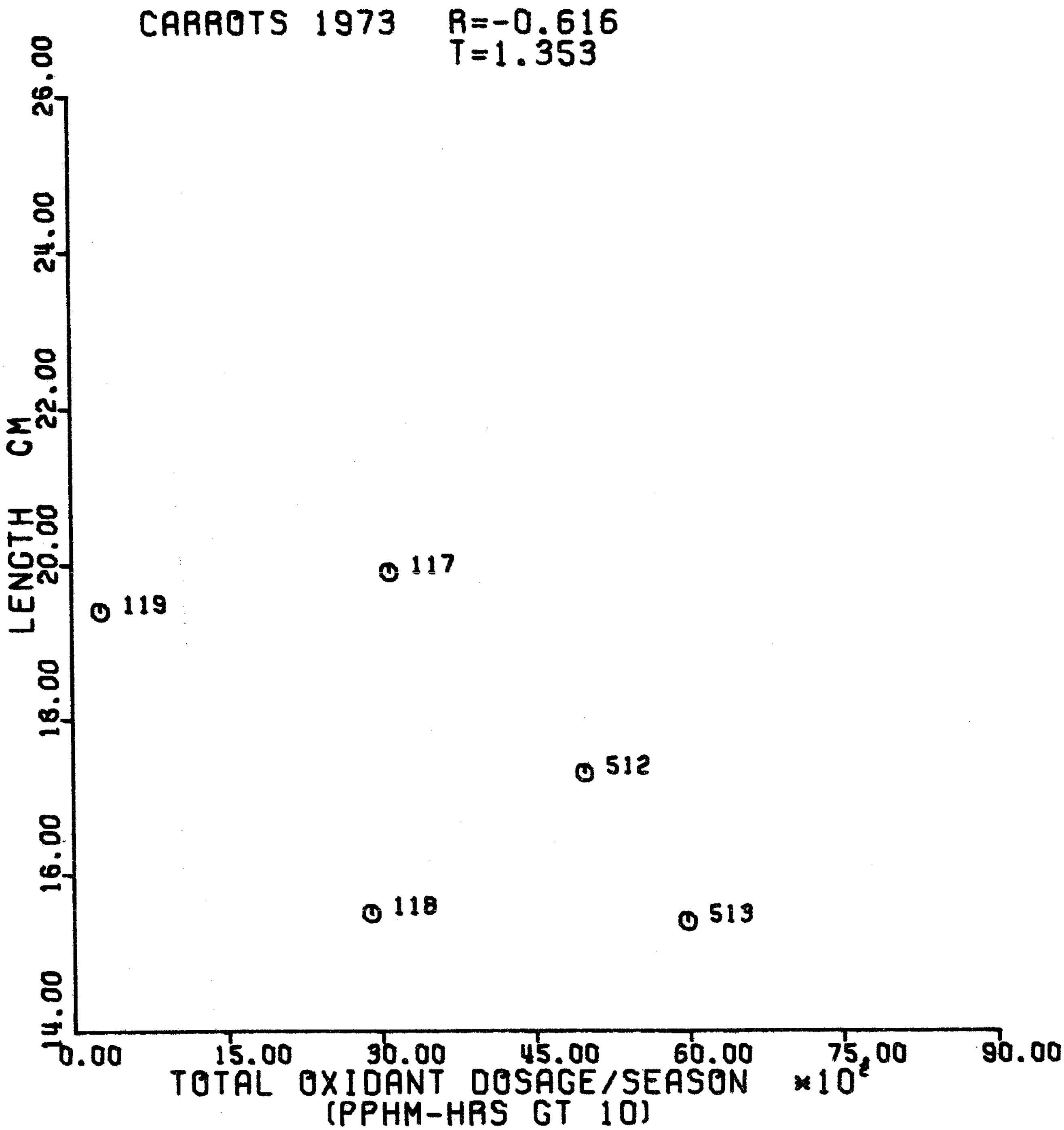


Figure 68. Correlation of weights of harvested Emperator #58 carrot roots with the total ambient dosage present during growth.

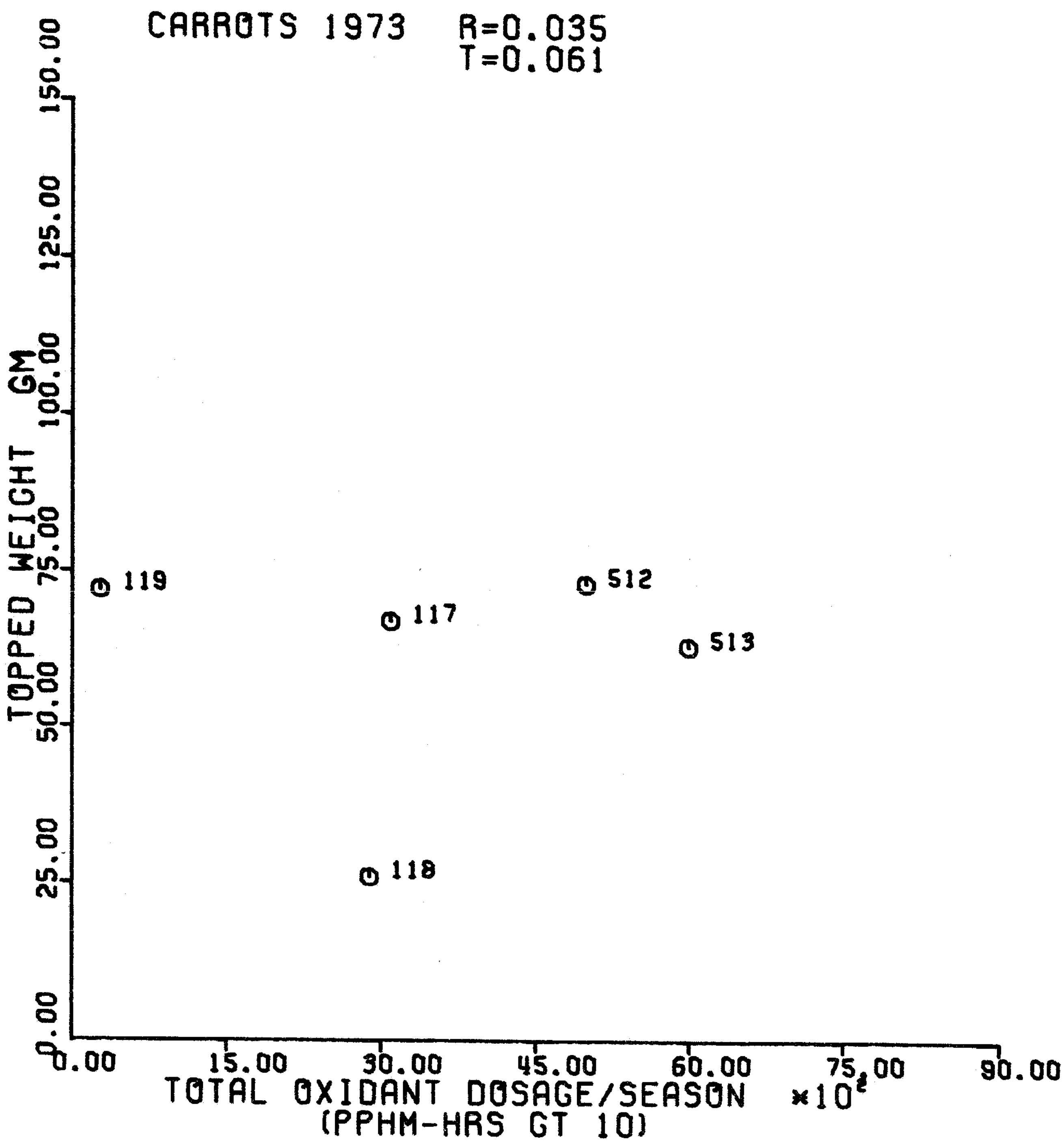


Figure 69. Correlation of weights of harvested Emperator #58 carrot roots with the total ambient dosage present during growth.

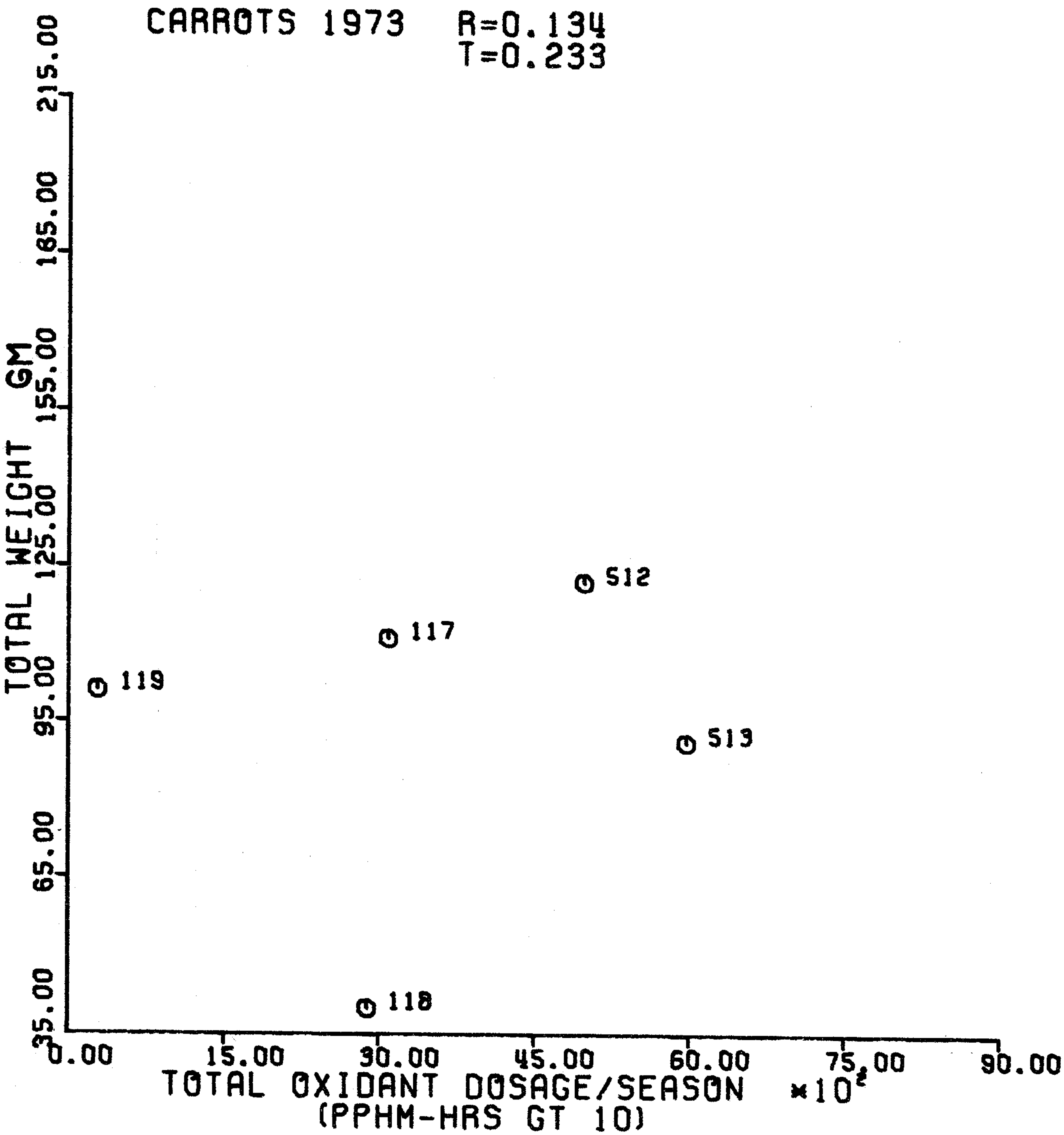


Figure 70. Correlation of diameters of harvested Emperator #58 carrot roots with the total ambient dosage present during growth.

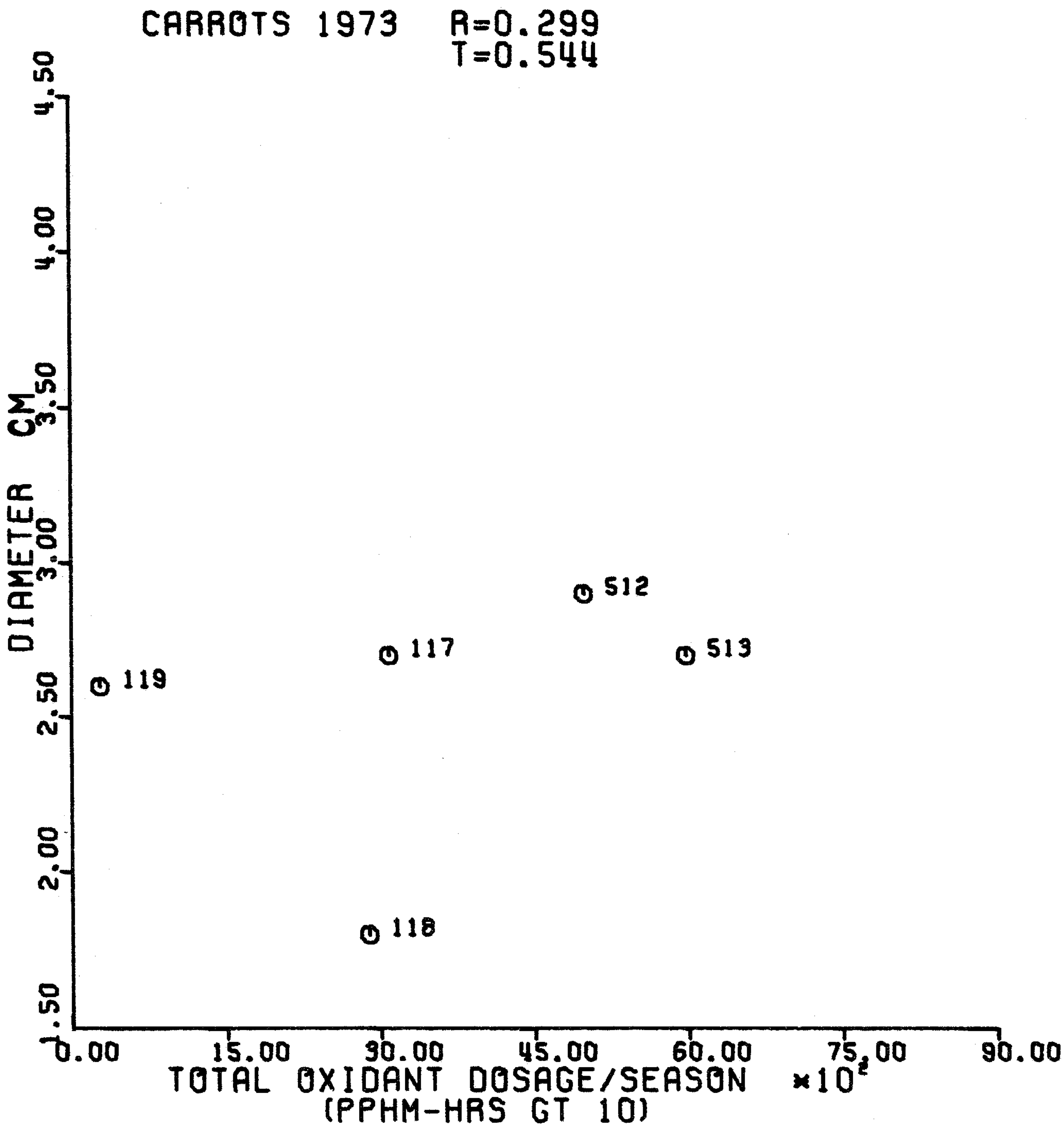


Figure 71. Correlation of the percent of irregular-shaped roots of harvested Emperator #58 carrot roots with the total ambient dosage present during growth.

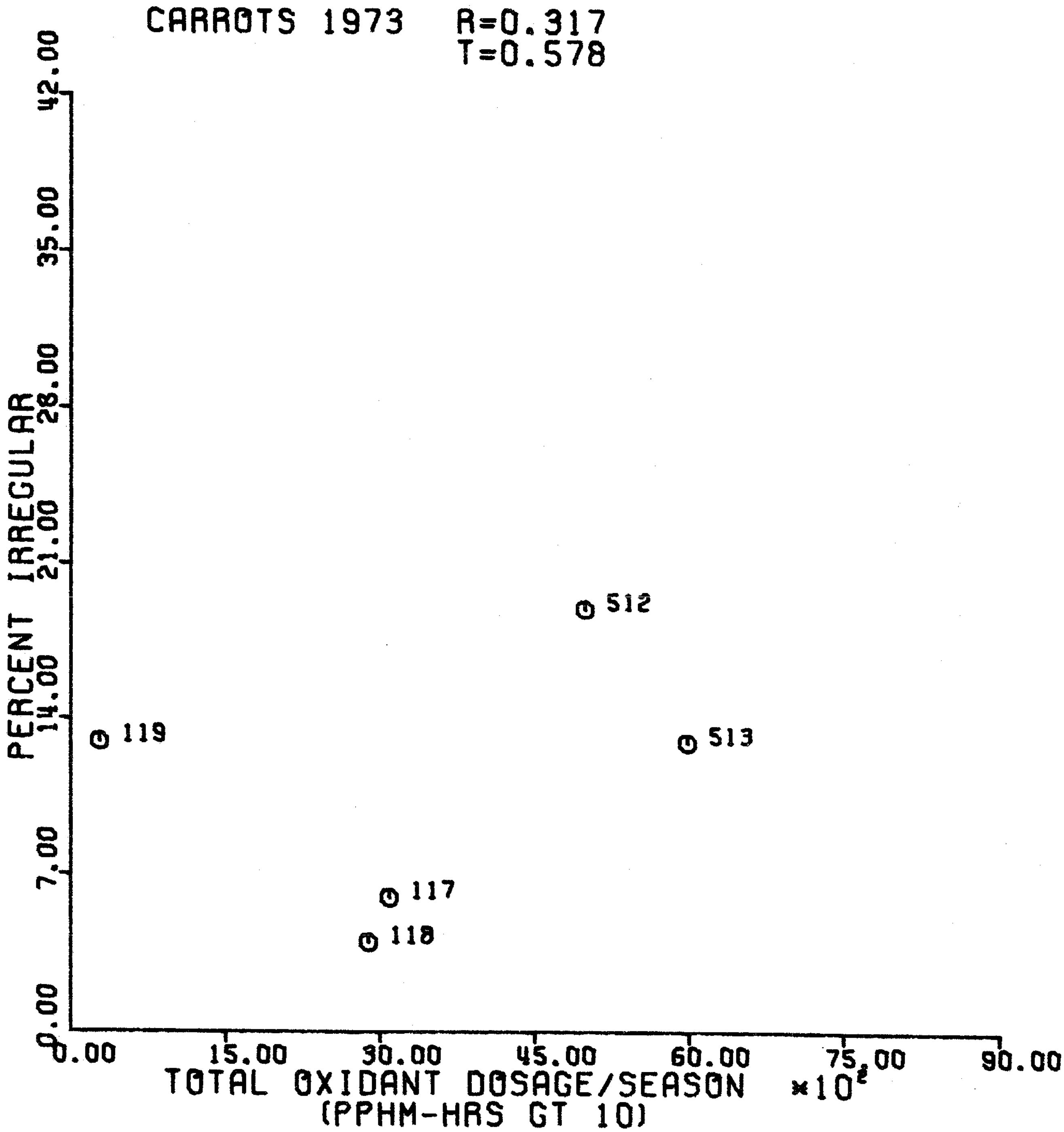


Figure 72. Correlation of the number of lateral roots of harvested Emperator #58 carrot roots with the total ambient dosage present during growth.

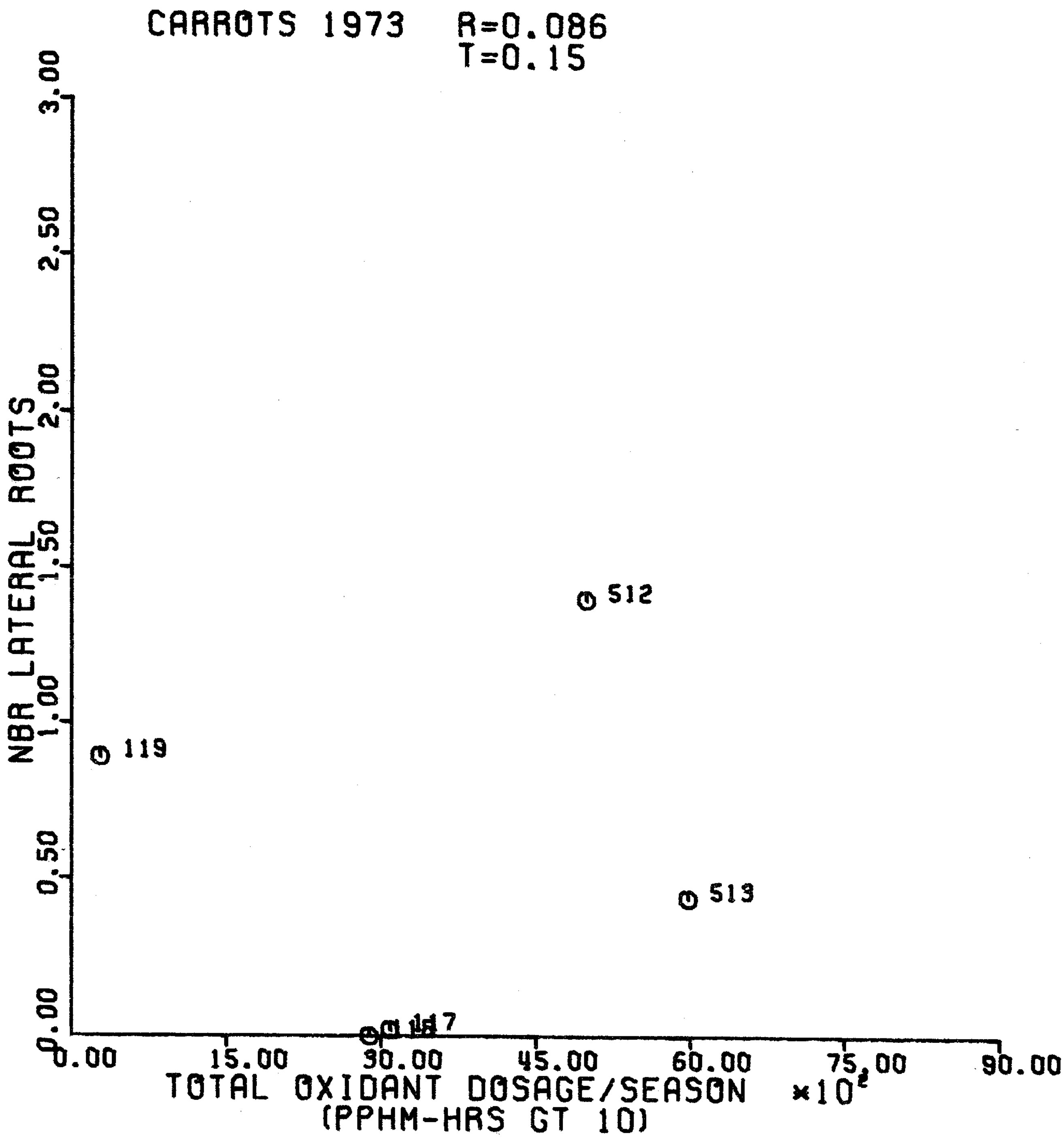


Figure 73. Correlation of the total number of leaves of harvested Emperator #58 carrot roots with the total ambient dosage present during growth.

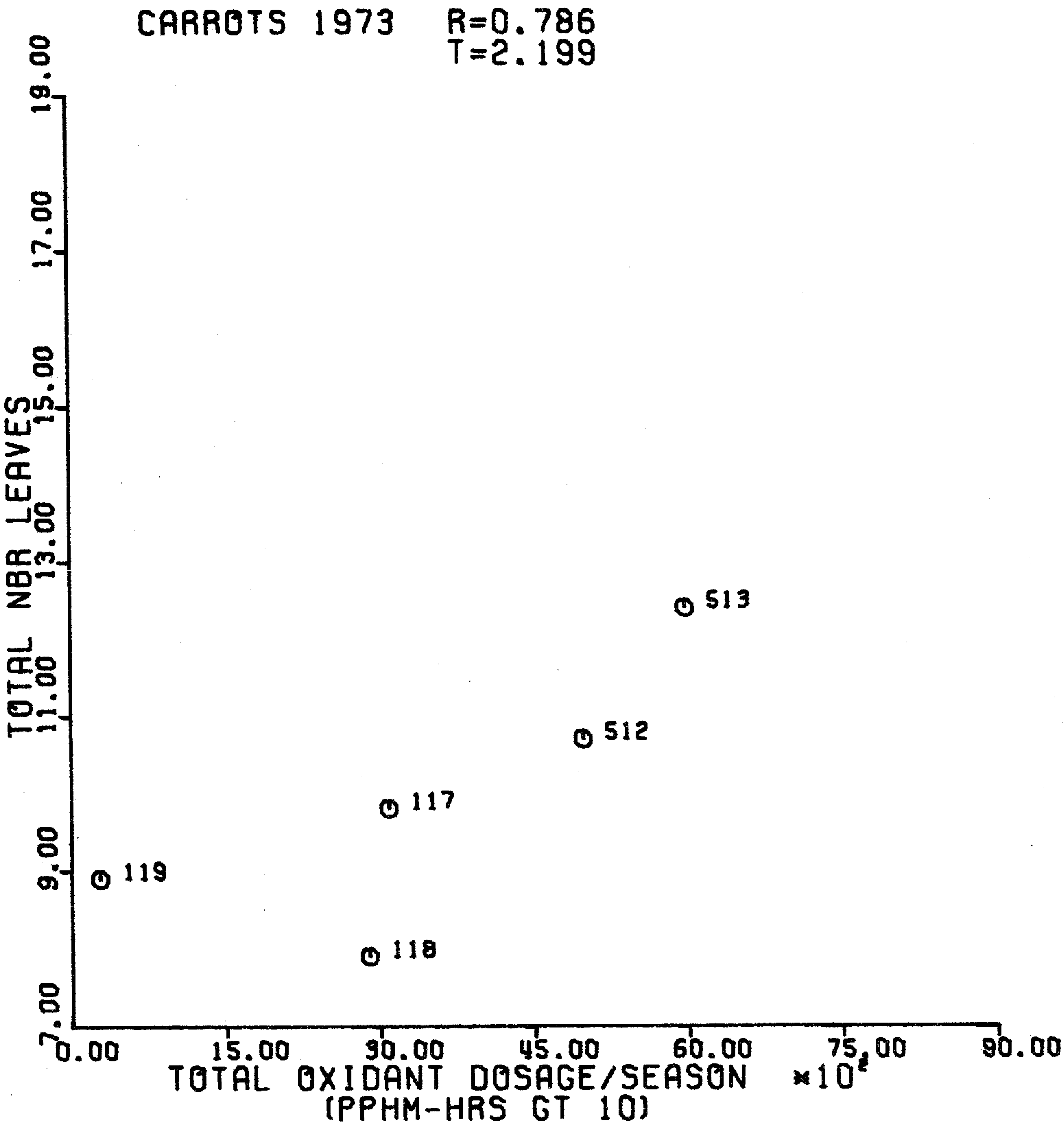
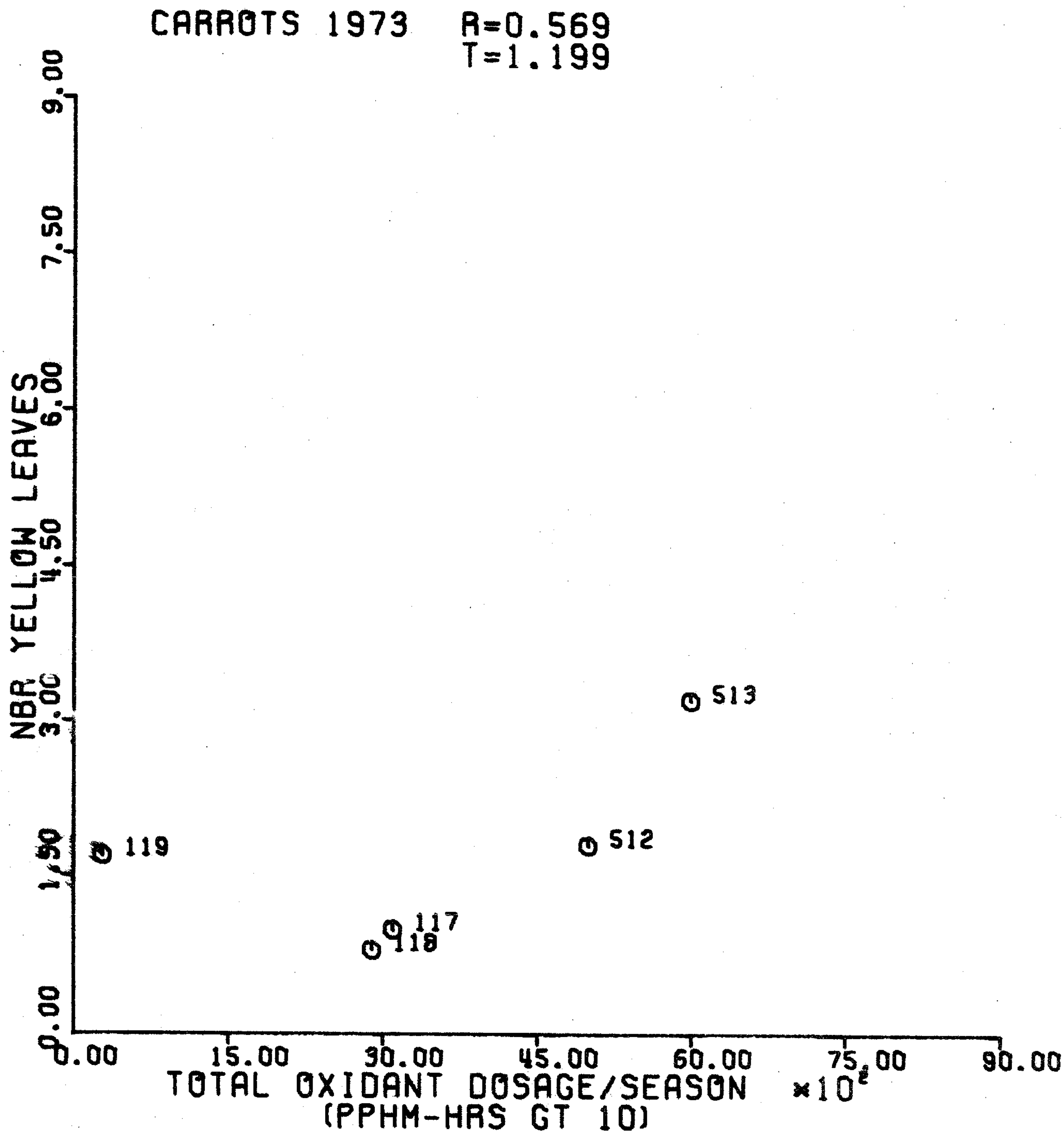


Figure 74. Correlation of the number of yellowed leaves of harvested Emperator #58 carrot roots with the total ambient dosage present during growth.



Introduction

Dark green Boston leaf lettuce was selected as the test variety for the 1973 yield study to replace the highly resistant Prizehead variety (bronze). This replacement proved to be timely as much of the 1973 fall lettuce crop in the South Coast Air Basin was rendered unmarketable by an air pollution episode. Field data was therefore available to check fumigation results.

Long-Term Ozone Fumigation

Treatments: 0 ppm ozone, .15 ppm ozone, .25 ppm ozone

Exposure: Treatments were exposed to the respective concentrations of fumigant 48 out of a total 750 hours or about 6% of the growing period. Fumigations were six hours in duration and at a frequency of 1.5 times a week.

Results: Ozone injury was observed on the leaves of both fumigated treatments and significantly affected the size of the plants (Table 18). The overall weights of plants did not reflect this effect as no differences were observed in dry weights between treatments. Significant differences were found in fresh weight measurements because many of the injured leaves contained dead tissue.

Nutritional Analyses of the 1972 Fumigation Studies (7)

All analyses were run with standard procedures utilized by the staff of the Western Regional Laboratory, United States Department of Agriculture, Berkeley, California.

I. PAN Fumigated Prizehead Lettuce

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Results: Fumigated plants were observed to contain higher levels of solids, calories, protein and nitrogen than control plants (Table 19). Fractional reductions in water content were also found to be significant. PAN exposures had no effect on metal or vitamin levels.

II. Ozone Fumigated Prizehead Lettuce

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Results: An unusual effect was noted in relation to the protein, nitrogen, and thiamine levels in the fumigated plants (Table 20). Plants within the .20 ppm ozone treatment exhibited reduced levels of these constituents whereas the .35 ppm fumigated plants were observed to have elevated levels. These results cannot be explained at this time. All other constituents tested did not differ among treatments.

Field Study

The 1973 field program utilized dark green Boston leaf lettuce. This is a popular variety in the South Coast Air Basin grown in the fall and spring growing seasons. Historically it has proven to be much more sensitive to oxidant air pollution injury than the Prizehead bronze variety used in the 1972 program.

Locations: Three commercial yield plots and three test plots of Boston lettuce were harvested (Map 8).

Sampling Techniques: Four plots containing 50 plants were established at emergence at each commercial field. Harvested plants were taken at ground level and evaluated the same day. Samples were stored in individual plastic bags until ready for evaluation.

Results: An extremely severe air pollution episode occurred in November of 1973 and effectively rendered mature heads of the Boston lettuce unmarketable (Appendix A). An analysis of the episode indicated the possible presence of PPN (peroxypropionyl nitrate), a homologue of PAN (peroxyacetyl nitrate), which is known to be from seven to ten times more toxic than PAN. However, high levels of ozone and PAN were also recorded for the same period of time and a significant amount of PAN type leaf injury was visible. Commercial and test plots in the Orange County area were severely injured and unmarketable.

An automated PAN-alyzer (electron capture chromatograph) at Garden Grove was operating during the episode and PAN dosages for Orange County field plots were calculated (Table 21). These dosages revealed that approximately 1/4 of the seasonal PAN dosage was present during a four-day period. This heavy exposure plus the possible presence of PPN would appear to explain the heavy injury.

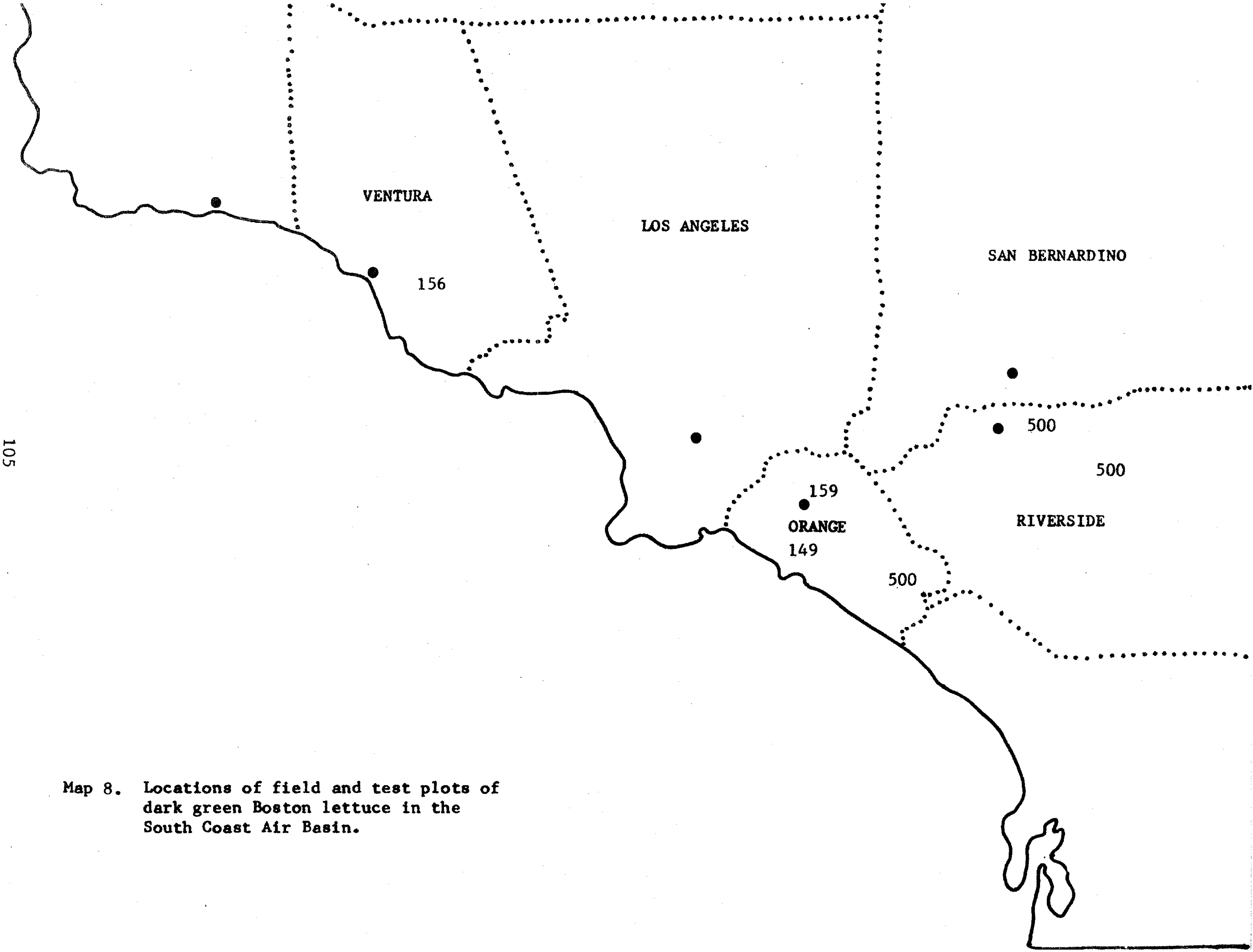
The PAN-alyzer at the University of California in Riverside was inoperative during the episode but foliar injury at both the UCR and Moreno test plots was heavy. The UCR planting was at a relatively young stage and eventually grew out of most of its injury but all harvested heads from the Moreno test plot were unmarketable.

Ozone dosages were within normal fall season levels but were slightly elevated during the November episode. However, the observed foliar injury was a PAN type of injury and not typical ozone symptomology. The correlations of evaluated crop characteristics and ozone dosages were not significant (Figures 75 - 79) and ozone did not appear to have influenced the leaf lettuce.

Discussion

The 1972 quality study indicated that leaf lettuce was the only crop found to be harmfully affected by PAN fumigations and only because aesthetic appearance was altered; however, no field data were found to support these fumigation results. The 1973 fall season clearly indicates that the fumigation results were consistent with what can occur in the field. The 608 ppb-hrs of PAN present during the November 8 -11 episode might be indicative of a very rough injury threshold for a short time period but this must be tempered with the fact that PPN may have induced much of the injury. The fact that most pollution instrument stations are not equipped to monitor PAN levels makes the threshold even more tenuous as many of the plots were a considerable distance from the Garden Grove instrument.

The nutritional analyses of PAN fumigated Prizehead lettuce indicated that PAN was responsible for increases in the levels of several constituents while the results from the ozone fumigated plants were somewhat confusing. Most other tested crops were found to have a greater response to ozone exposures and little response to PAN fumigations.



Map 8. Locations of field and test plots of dark green Boston lettuce in the South Coast Air Basin.

Table 18. Summary of significant ozone effects on Boston lettuce as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Height	Plant Diameter	No Leaves	No. Injured Leaves[1/]
Ozone	0	- a[2]	- a A[3]	- a	0 a A
Treatments	.15	- a	4.51 b A	- a	5.6 b B
(ppm)	.25	- a	8.8 c A	- a	17.9 c C

		Fresh Wt. Leaves	Dry Wt. Leaves	Dry Wt. Roots	Total Dry Wt.
Ozone	0	- a A	- a	- a	- a
Treatments	.15	-2.26[4] a A	- a	- a	- a
(ppm)	.25	19.13 b B	- a	- a	- a

1. Figures given in this category represent the treatment means and not calculated percent reductions from the control treatments.

2. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

3. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

4. A minus percent reduction represents a percent increase over the control treatment.

Table 19. Summary of the effects of PAN on nutritional constituents in Prizehead lettuce as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Solids	Water	Niacin	Riboflavin	Vitamin A
PAN	0	- a[1] A[2]	- a A	- a	- a	- a
Treatments	20	-10.24[3] b B	0.52 b B	- a	- a	- a
(ppb)	40	-7.35 b AB	0.37 b AB	- a	- a	- a

		Vitamin C	Calories	Ash	Fiber	Carbohydrate	Protein
PAN	0	- a	- a A	- a	- a	- a	- a A
Treatments	20	- a	-10.59 b B	- a	- a	- a	-9.96 b B
(ppb)	40	- a	-8.82 b AB	- a	- a	- a	-6.45 b AB

		Thiamine					
		Thiochrome	Microbiol	Ca	Pb	Fe	Cu
PAN	0	- a	- a	- a	- a	- a	- a
Treatments	20	- a	- a	- a	- a	- a	- a
(ppb)	40	- a	- a	- a	- a	- a	- a

		N	Mn	K	Zn	Sr
PAN	0	- a A	- a	- a	- a	- a
Treatments	20	-9.76 b B	- a	- a	- a	- a
(ppb)	40	-6.1 b AB	- a	- a	- a	- a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 20. Summary of the effects of ozone on nutritional constituents in Prizehead lettuce as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Solids	Water	Fiber	Ash	Protein
Ozone	0	- a[1]	- a	- a	- a	- a AB[2]
Treatments	.20	- a	- a	- a	- a	9.03 b A
(ppm)	.35	- a	- a	- a	- a	-8.33[3] c B

		Calories	Vitamin A	Vitamin C	Ca	Pb	Fe
Ozone	0	- a	- a	- a	- a	- a	- a
Treatments	.20	- a	- a	- a	- a	- a	- a
(ppm)	.35	- a	- a	- a	- a	- a	- a

		Cu	Mn	K	N	Zn	Sr
Ozone	0	- a	- a	- a	- a AB	- a	- a
Treatments	.20	- a	- a	- a	8.69 b A	- a	- a
(ppm)	.35	- a	- a	- a	-8.69 c B	- a	- a

		Thiamine				
		Thiochrome	Microbiol	Riboflavin	Niacin	Carbohydrate
Ozone	0	- a A	- a	- a	- a	- a
Treatments	.20	3.88 a A	- a	- a	- a	- a
(ppm)	.35	-16.5 b A	- a	- a	- a	- a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 21. Calculated PAN dosages for Orange County field and test plots.

Seasonal Dosage

Location	Dates	PAN Dosage in ppb-hrs
159	8/15/73 - 11/4/73	2154
149	9/21/73 - 11/19/73	2386
584	9/4/73 - 11/11/73	2716

Episode Dosage

Location	Dates	PAN Dosage in ppb-hrs
149	11/8/73 - 11/11/73	608
584	11/8/73 - 11/11/73	608

Figure 75. Correlation of heights of harvested Boston lettuce heads with the total ambient oxidant dosage present during growth.

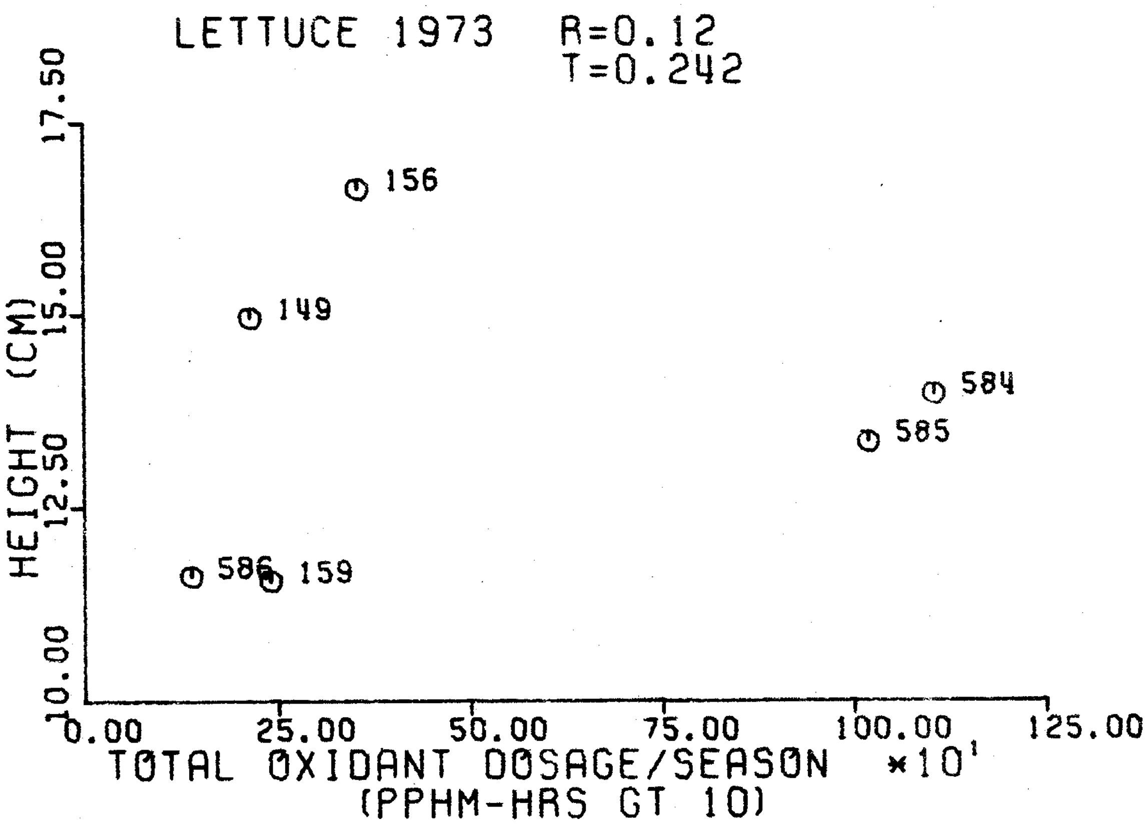


Figure 76. Correlation of diameters of harvested Boston lettuce heads with the total ambient oxidant dosage present during growth.

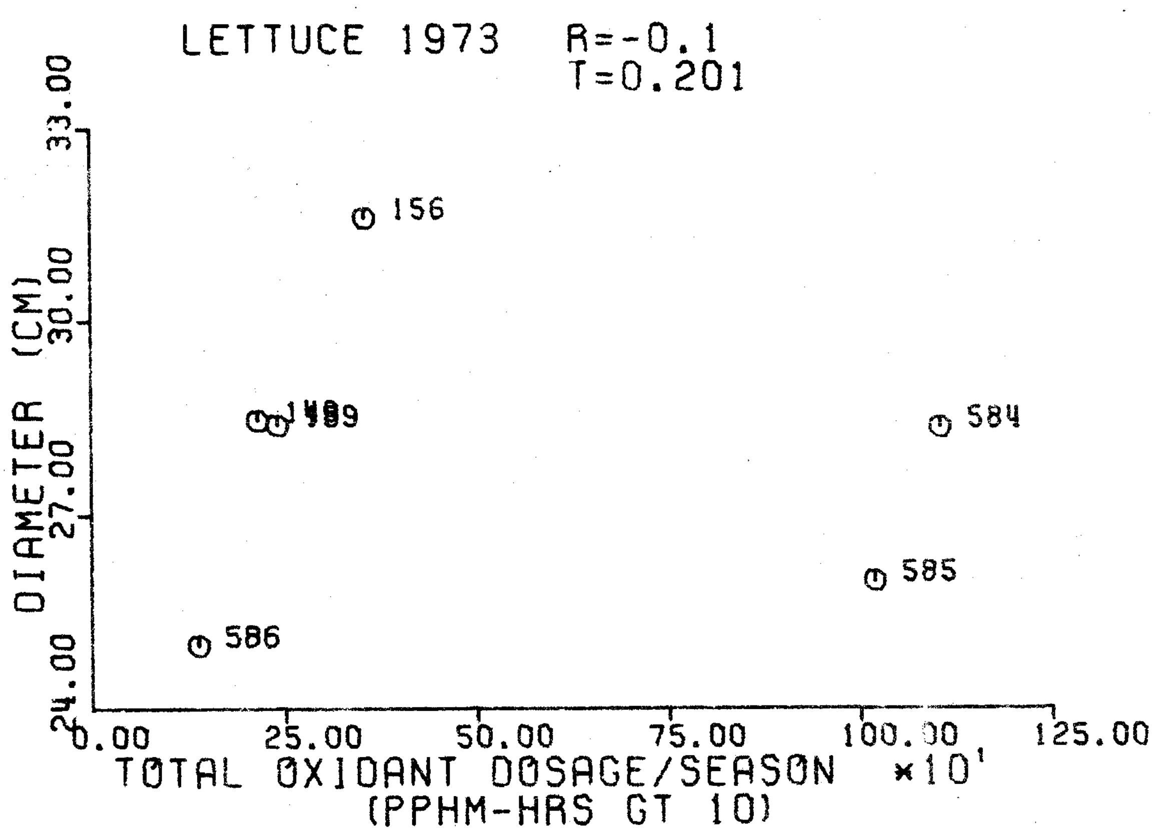


Figure 77. Correlation of weights of harvested Boston lettuce heads with the total ambient oxidant dosage present during growth.

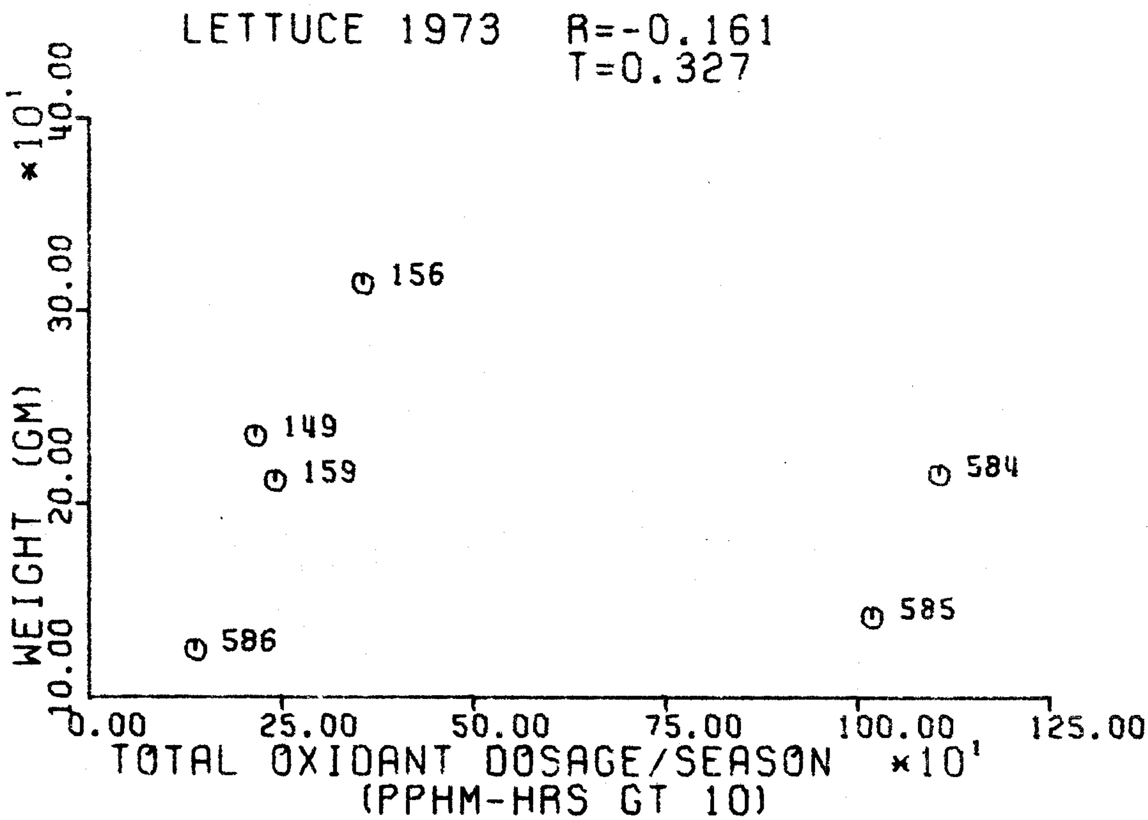


Figure 78. Correlation of the number of injured leaves on harvested Boston lettuce heads with the total ambient oxidant dosage present during growth.

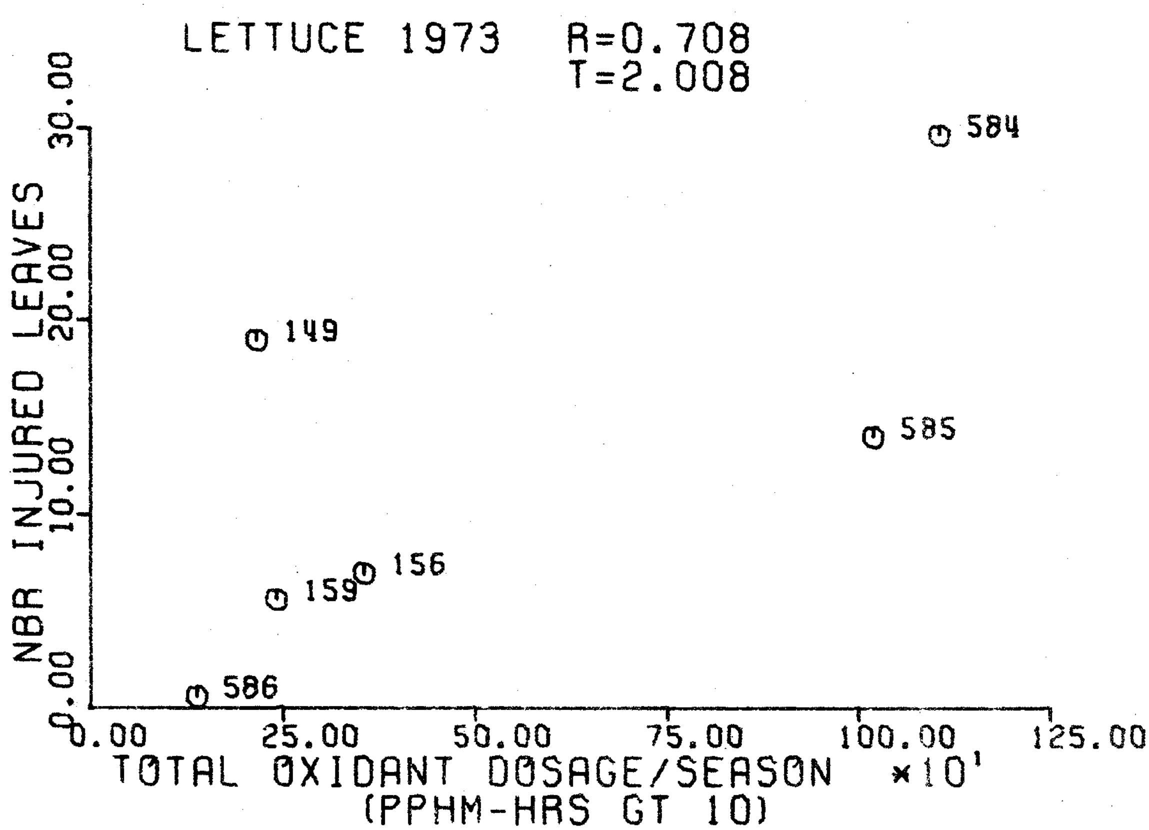
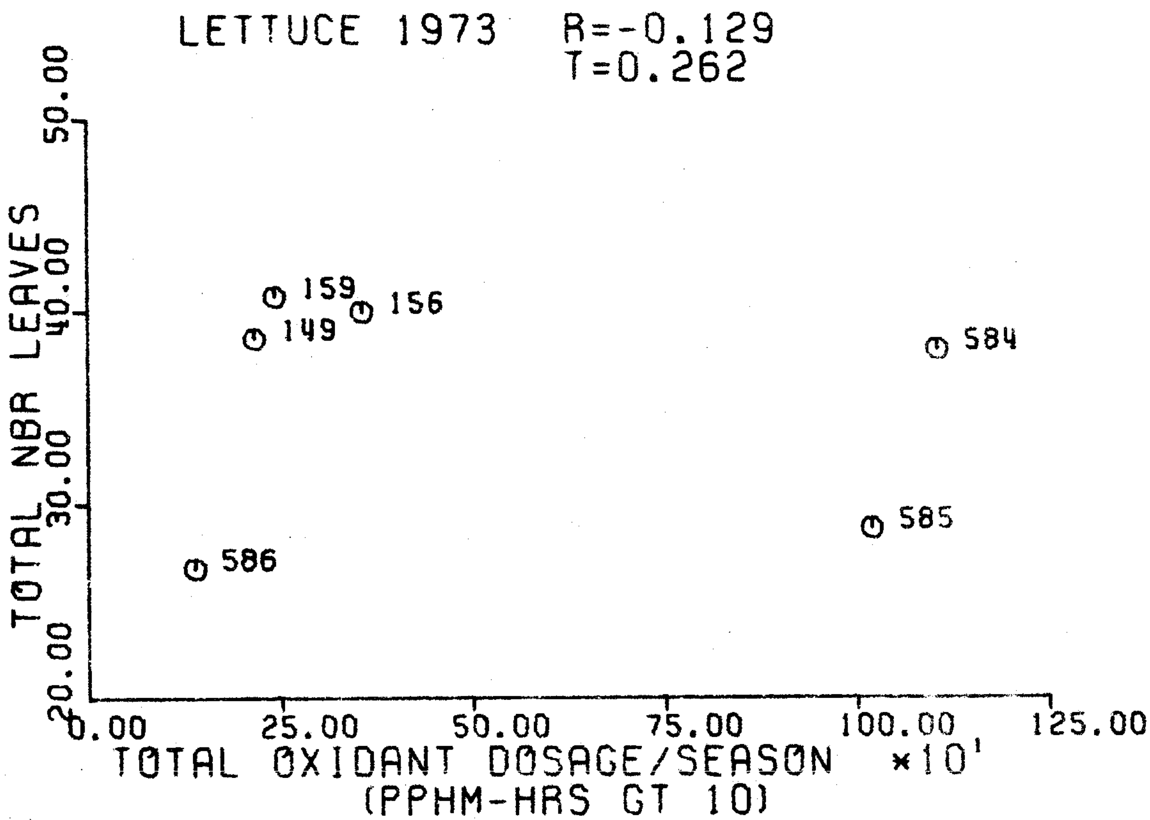


Figure 79. Correlation of the number of leaves of harvested Boston lettuce heads with the total ambient oxidant dosage present during growth.



Introduction

Greenback cabbage was used to replace the ozone resistant Copenhagen Market variety in the 1973 yield study. Unfortunately, this variety proved to be even more resistant to ozone. It was also found to be extremely slow growing and therefore unacceptable to many growers. Commercial growers are replacing it with faster growing, better yielding varieties.

Long-Term Ozone Fumigation

Treatments: 0 ppm ozone, .15 ppm ozone, .25 ppm ozone

Exposure: Treatments were exposed to the respective concentrations of fumigant 180 out of a total 2300 hours or about 7.7% of the growing period. Fumigations were six hours in duration and at a frequency of 1.5 times a week.

Results: No foliar ozone injury was observed on fumigated treatment plants during the experiment. Ozone exposures generally appeared to stimulate head formation (Table 22). Harvested cabbage heads from the fumigated treatment plants were found to be larger than control plants as measured by head diameter and fresh weight. However, plant measurements within the three treatments were not significantly different as plant diameters and total weights did not differ statistically. The biomass of the control plants was in the form of wrapper leaves and not in head size.

The ozone effects on Greenback cabbage did not follow the same pattern as the 1972 ozone fumigations of Copenhagen Market or Jet Pack cabbage where ozone exposures reduced the size of the harvested heads and the plants as a whole. The differences may be due to varietal variability or possibly the ozone exposure schedules but further study would be needed to determine the reason.

The Greenback variety was not found to be as desirable as Copenhagen Market or Jet Pack in spite of its resistance to foliar injury. It required an excessive amount of time from seeding to harvest and produced smaller heads.

Nutritional Analyses of 1972 Fumigation Studies

All analyses were run with standard procedures utilized by the staff of the Western Regional Laboratory, United States Department of Agriculture, Berkeley, California.

I. PAN Fumigated Copenhagen Market Cabbage

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Results: PAN had no significant effect on the nutritional levels measured in the Copenhagen Market cabbage heads (Table 23). Only an increase in the calcium level in high fumigation heads proved to be significant.

II. Ozone Fumigated Copenhagen Market Cabbage

Treatments: 0 ppm, .20 ppm, .35 ppm

Results: Ozone exposure appeared to trigger significant increases in vitamin C, thiamine, and potassium (Table 24). The levels of solids, calories and water within the high fumigation treatment heads were also significantly higher than the control and low fumigation treatment heads. Only the lead concentration within heads was reduced in association with ozone exposures and only at the .05 level. The apparent stimulation of increases in the levels of of many constituents was not expected and cannot be explained at this time.

Field Study

Many commercial growers tried the Greenback variety of cabbage in the fall of 1973 to avoid Copenhagen Market's tendency to burst during shipping and storage. Unfortunately, this variety proved unacceptable as a replacement due to its excessively long period of growth to harvest and reduced yield per acre. Few growers were planning to use Greenback again after their experience in 1973.

Locations: Five commercial yield plots and three test plots of Greenback cabbage were harvested (Map 9).

Sampling Techniques: Four plots totaling 50 plants were established at emergence at each commercial field. Each harvested plant was taken at ground level and evaluated. Total plant measurements included the harvested head.

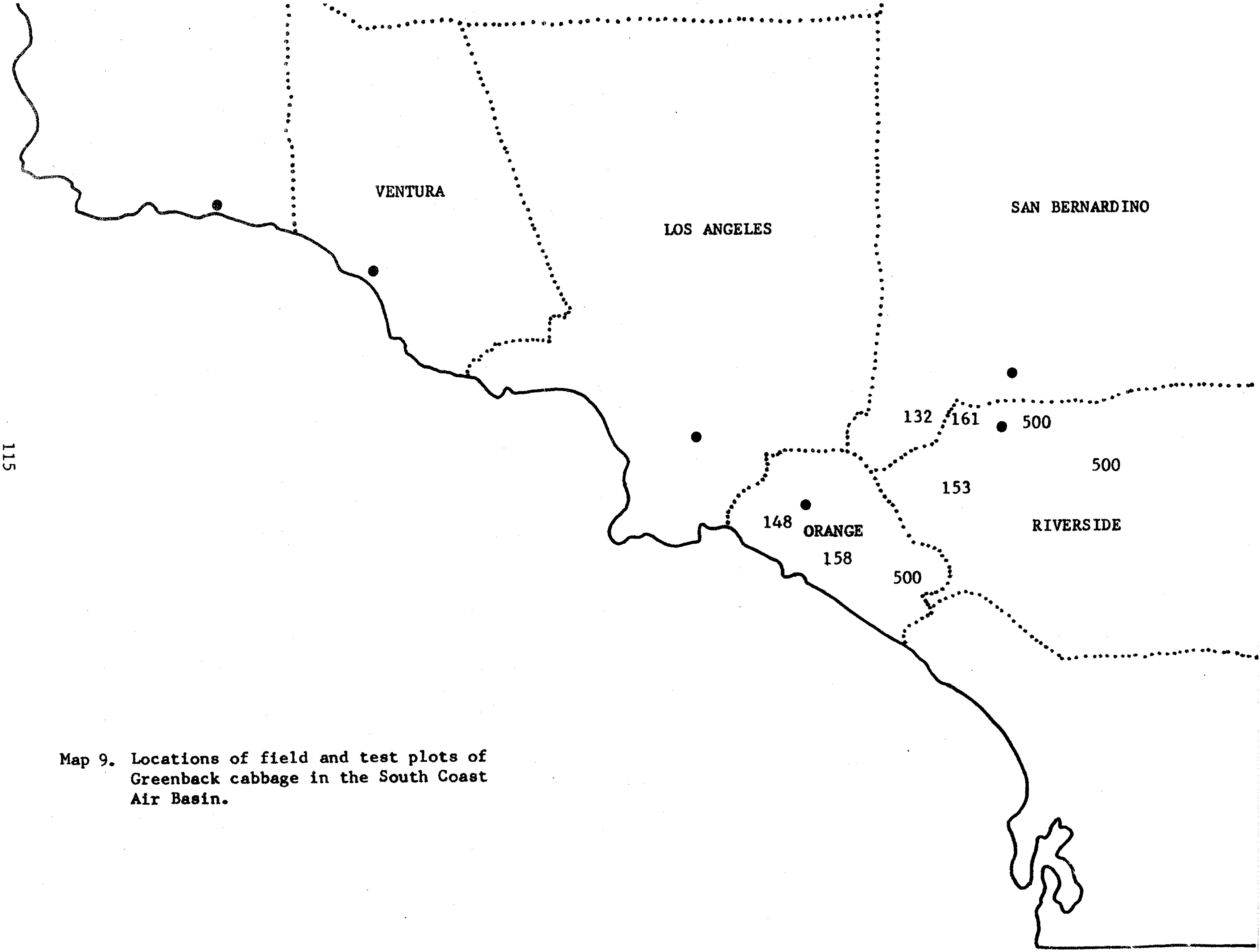
Results: No measured Greenback cabbage parameter was significantly correlated with ozone dosage (Figures 80-84) nor was any foliar ozone injury observed in the field.

Discussion

Greenback cabbage was observed to be stimulated to head formation during ozone fumigations. The long-term exposures did not produce foliar injury or any measurable reductions in plant growth or yield. Field studies showed no significant correlations of yield or quality with ozone dosages.

The nutritional studies of ozone fumigated Copenhagen Market cabbage heads were generally found to contain higher levels of many nutrients and solids than control heads. The overall effect of ozone on Copenhagen Market heads was a reduction in fresh weight and size, but higher levels of certain nutritional constituents.

The two-year study of ozone effects on the yield and quality of cabbage produced no record of ambient ozone concentrations injuring leaves or influencing yield reductions. Fumigated varieties varied in their response to ozone from obvious reductions in yield to an apparent stimulation of head formation, but were exposed to much higher concentrations than normal ambient dosages. The evidence indicates that ambient ozone concentrations apparently do not affect the growth, yield, or quality of the three commercial cabbage varieties tested.



Map 9. Locations of field and test plots of Greenback cabbage in the South Coast Air Basin.

Table 22. Summary of significant ozone effects on Greenback cabbage as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Plant Height	Plant Diameter	No.Wrapper Leaves	No.Injured Leaves
Ozone	0	- a[1]	- a A[2]	- a A	- a
Treatments	.15	- a	13.83 b B	7.34 a AB	- a
(ppm)	.25	- a	16.81 b B	29.82 b B	- a

		Total Fresh Wt.	Fresh Wt. Leaves & Stems	Head Ht.	Head Diameter
Ozone	0	- a	- a	- a	- a A
Treatments	.15	- a	- a	- a	-3.8[3] a AB
(ppm)	.25	- a	- a	- a	-22.39 b B

		Fresh Wt. Head	Dry Wt. Leaves & Stems	Dry Wt. Roots	Total Dry Wt.
Ozone	0	- a A	- a	- a	- a
Treatments	.15	-6.33 a A	- a	- a	- a
(ppm)	.25	-67.51 b A	- a	- a	- a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 23. Summary of the effects of PAN on nutritional constituents in Copenhagen cabbage as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Protein	Solids	Water	Riboflavin	Niacin
PAN	0	- a[1]	- a	- a	- a	- a
Treatments	20	- a	- a	- a	- a	- a
(ppb)	40	- a	- a	- a	- a	- a

		Thiamine Thiochrome	Thiamine Microbiol	Calories	Ash	Carbohydrates	Fiber
PAN	0	- a	- a	- a	- a	- a	- a
Treatments	20	- a	- a	- a	- a	- a	- a
(ppb)	40	- a	- a	- a	- a	- a	- a

		Nitrogen	Vitamin A	Vitamin C	Zn	Sr	Mn
PAN	0	- a	- a	- a	- a	- a	- a
Treatments	20	- a	- a	- a	- a	- a	- a
(ppb)	40	- a	- a	- a	- a	- a	- a

		K	Fe	Cu	Ca	Pb
PAN	0	- a	- a	- a	- a A[2]	- a
Treatments	20	- a	- a	- a	-0.34[3] a A	- a
(ppb)	40	- a	- a	- a	-34.3 b B	- a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 24. Summary of the effects of ozone on nutritional constituents in Copenhagen cabbage as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Solids			Water			Riboflavin		Niacin	
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	-	a
Treatments	.20	-6.94[3]	a	AB	0.48	a	AB	-	a	-	a
(ppm)	.35	-26.32	b	B	1.9	b	B	-	a	-	a

		Thiamine										
		Thiachrome			Microbiol			Vitamin A		Vitamin C		
Ozone	0	-	a	A	-	a	A	-	a	-	a	A
Treatments	.20	-13.04	a	AB	-8.59	a	AB	-	a	-9.63	a	A
(ppm)	.35	-47.83	b	B	-58.9	b	B	-	a	-57.95	b	B

		Zn		Sr		Mn		K			Ca	
Ozone	0	-	a	-	a	-	a	-	a	A	-	a
Treatments	.20	-	a	-	a	-	a	-19.75	a	A	-	a
(ppm)	.35	-	a	-	a	-	a	-70.59	b	B	-	a

		Pb			Fe		Cu		Calories			Nitrogen	
Ozone	0	-	a	A	-	a	-	a	-	a	A	-	a
Treatments	.20	11.63	a	A	-	a	-	a	-21.81	ab	A	-	a
(ppm)	.35	71.51	b	A	-	a	-	a	-45.83	b	A	-	a

		Ash			Carbohydrates			Fiber			Protein	
Ozone	0	-	a	A	-	a	A	-	a	A	-	a
Treatments	.20	-10.64	a	A	-28.97	b	A	-13.24	b	A	-	a
(ppm)	.35	-57.45	b	B	-43.09	b	A	-42.65	c	B	-	a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Figure 80. Correlation of fresh weights of harvested Greenback cabbage plants with the total ambient dosage present during growth.

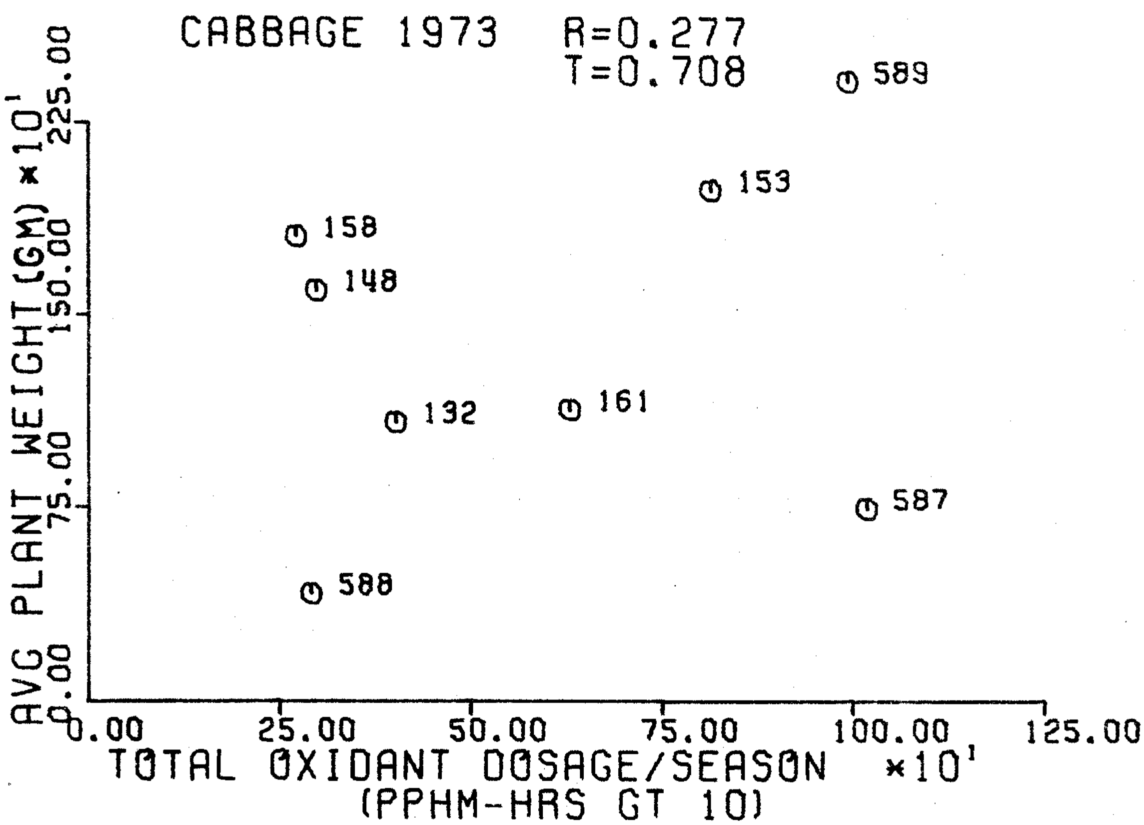


Figure 81. Correlation of the number of wrapper leaves of harvested Greenback cabbage plants with the total ambient dosage present during growth.

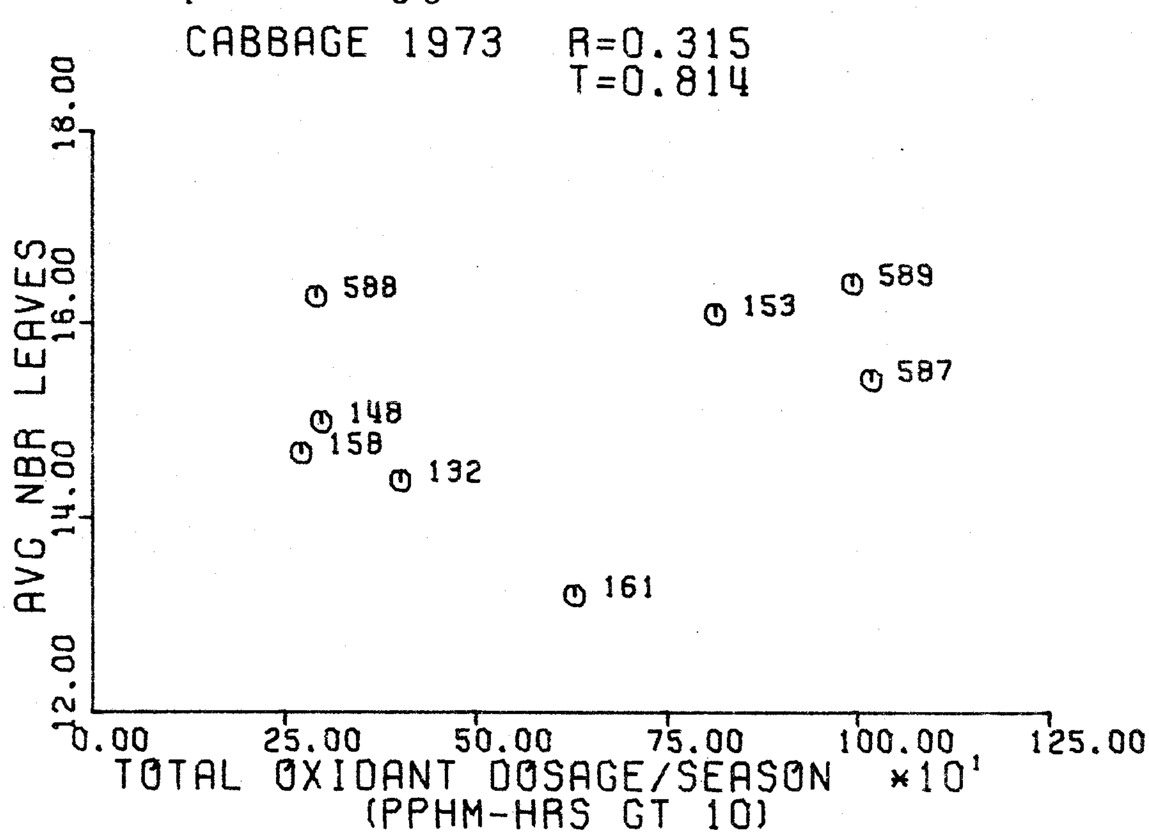


Figure 82. Correlation of diameters of harvested Greenback cabbage heads with the total ambient dosage present during growth.

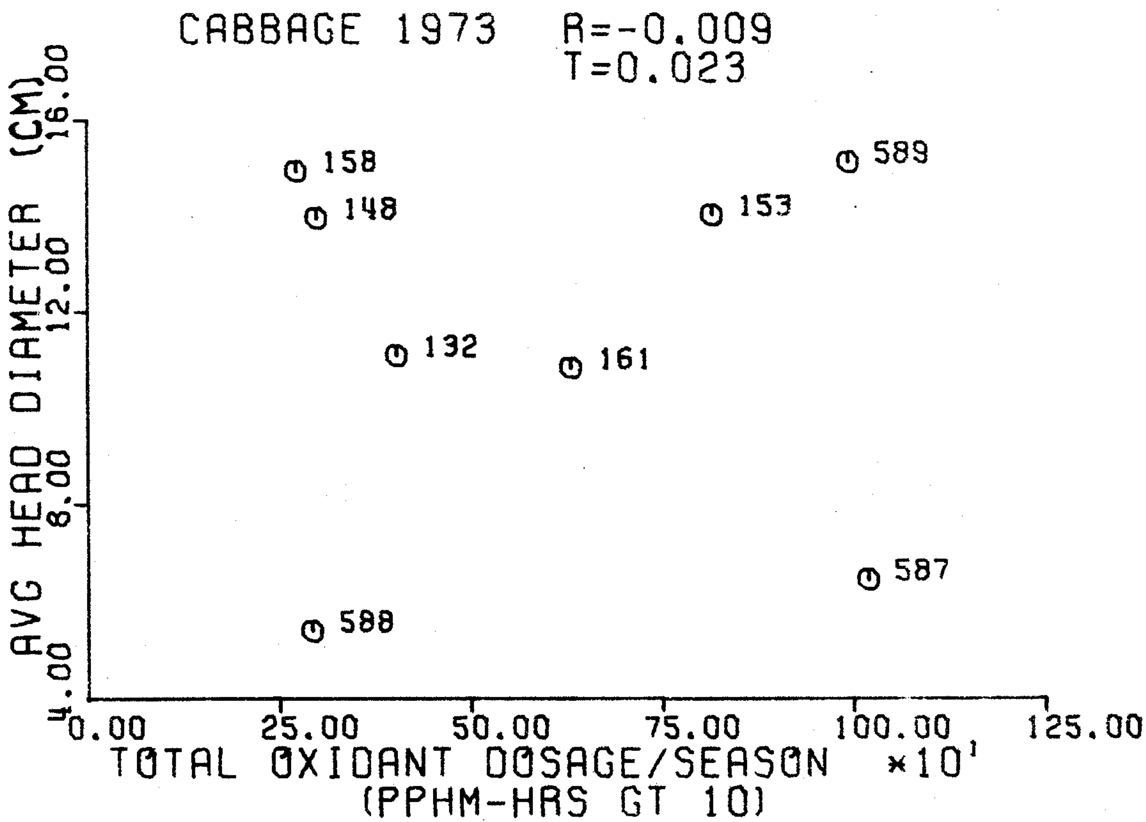


Figure 83. Correlation of fresh weights of harvested Greenback cabbage heads with the total ambient dosage present during growth.

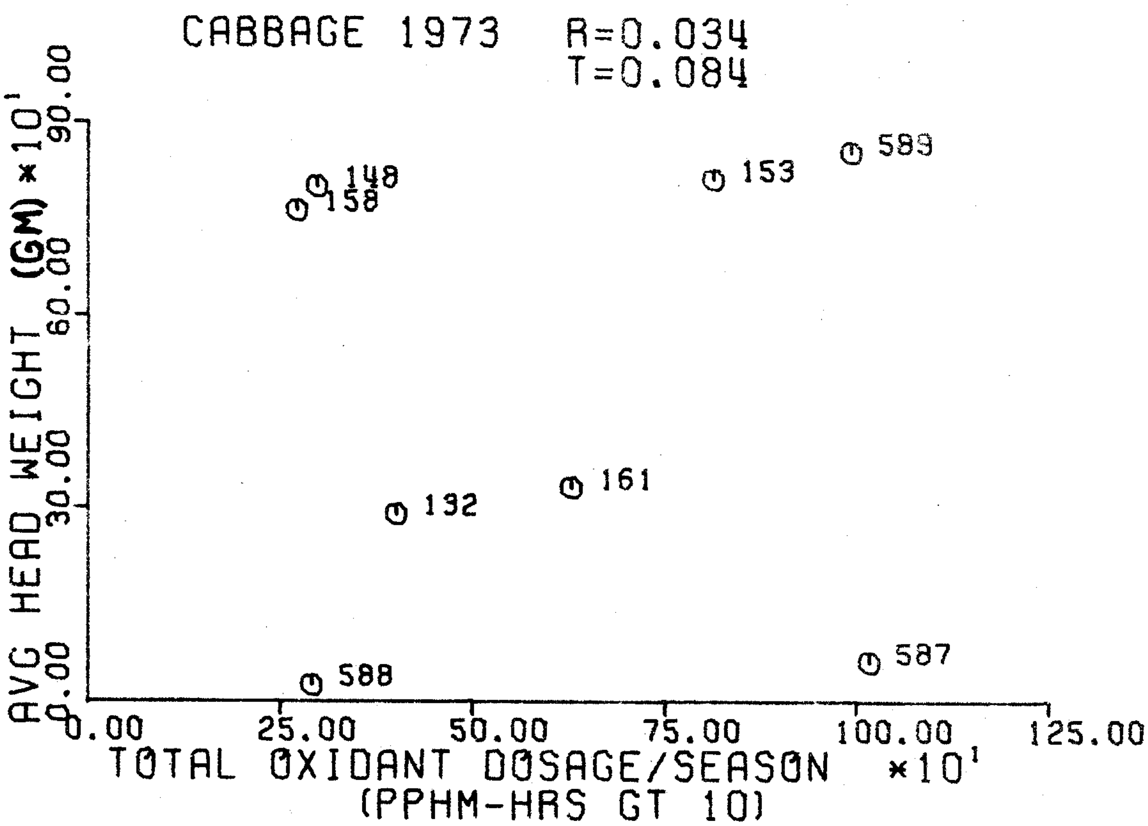
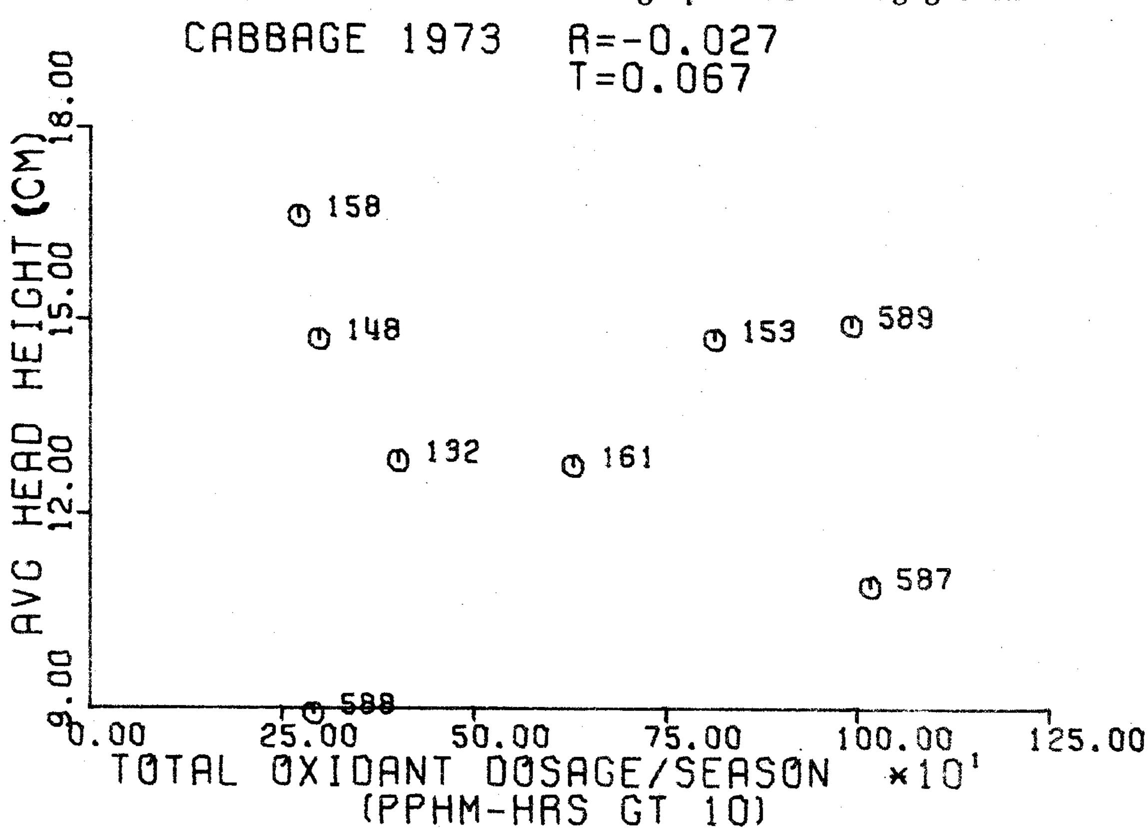


Figure 84. Correlation of heights of harvested Greenback cabbage heads with the total ambient dosage present during growth.



Introduction

Tioga strawberries are the most popular commercial variety planted in the South Coast Air Basin. The summer plantings are established early in August and harvested from April through June of the following year. Strawberries are a multiple harvest crop which require continual picking throughout the harvest season.

Long-Term Ozone Fumigation

Treatments: 0 ppm ozone, .25 ppm ozone, .30 ppm ozone

Exposure: Treatments were exposed to their respective concentrations of fumigant 146 out of a total of 1944 hours or about 7.7% of the growing period. Fumigations were 6 hours in duration and at a frequency of 1.5 times a week. Fumigations were run from August through October in 1973 to simulate the field situation.

Results: Only harvest records were collected as plants are normally trimmed extensively in the winter and plant measurements would have been futile. The .30 ppm treatment plants were found to yield fewer berries and a corresponding decrease in weight (Table 25). The percentage of irregularly-shaped berries increased with ozone dosage as the high fumigation plants produced 17% more irregular fruit than the other two treatments. Harvested berries from each treatment were found to be of uniform size when average berry weights were calculated for the season.

Nutritional Analyses of 1972 Fumigation Studies (7)

All analyses were run with standard procedures utilized by the staff of the Western Regional Laboratory, United States Department of Agriculture, Berkeley, California.

I. PAN Fumigated Tioga Strawberry Fruit

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Results: With the exception of strontium, no level of constituents tested were observed to have ozone-induced differences (Table 26).

II. Ozone Fumigated Tioga Strawberry Fruit

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Results: Ozone did not appear to cause variations in the nutritional composition of fruit harvested from the three treatments. Only an unusual increase in available iron within the .35 ppm ozone fumigated berries appeared to be significantly associated with ozone and the significance of this increase was not understood (Table 27).

Field Study

The problems experienced in tomato harvests (multiple harvests) were prophetic in regard to harvesting strawberry plots. A total of nine commercial plots were originally established for yield studies but were abandoned when the man hour requirement for harvesting was calculated. The lack of control over commercial harvesting crews was another reason yield harvests were not initiated. The frustrating experience gained in the spring of 1973 relative to isolating plots from a tomato harvesting crew at one commercial location would have been multiplied nine fold. Test plots were established at Riverside and South Coast Field Station to compare yields of plants grown in two very different climates and pollution levels. These harvest records did not isolate ozone effects but provided interesting differences which might be useful in guiding future studies.

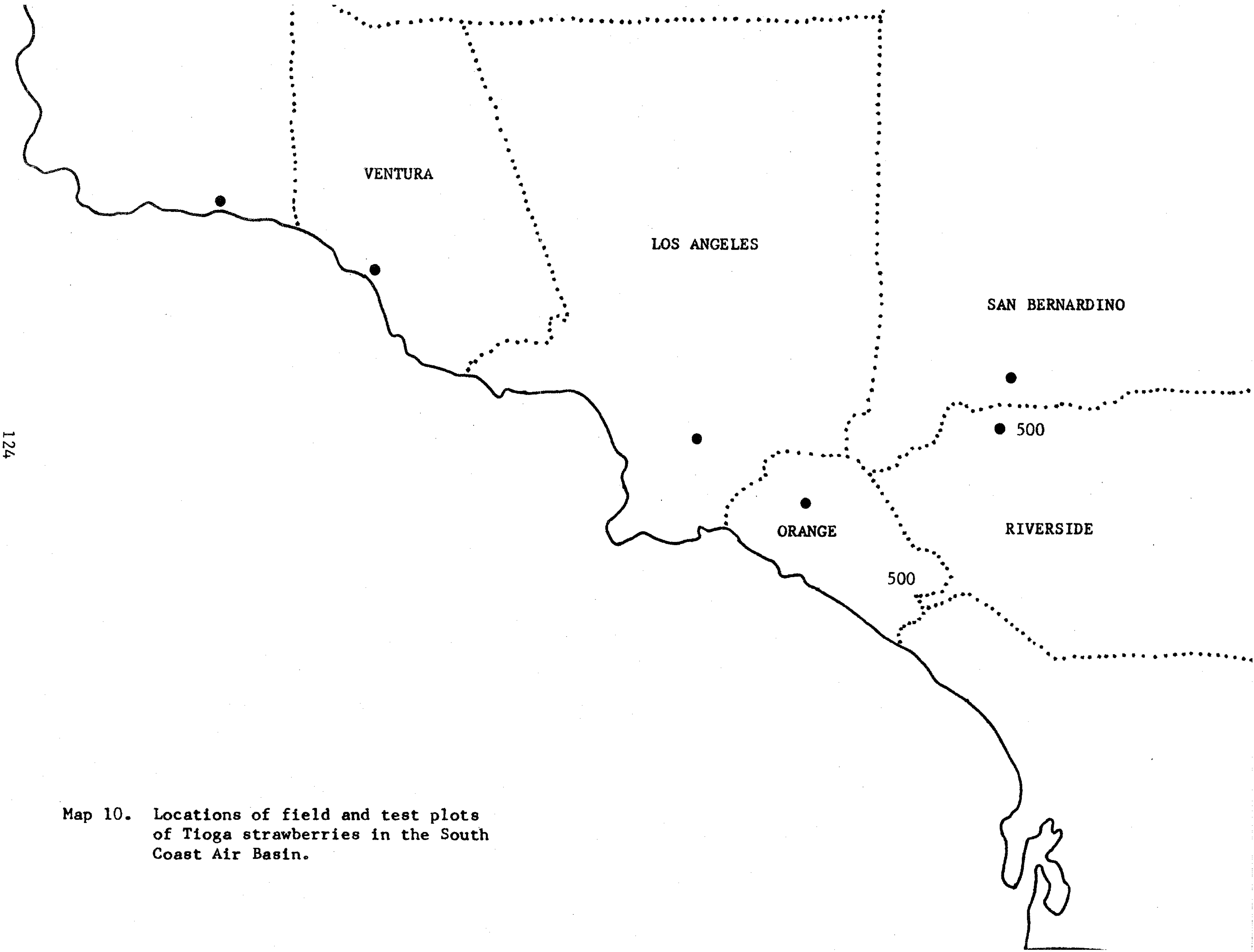
Locations: Two test plots of Tioga strawberries were harvested (Map 10).

Results: Comparisons of the total yields at each test plot revealed that the South Coast Field Station plot produced almost twice as many berries with a corresponding difference in total weight (Figures 85, 86). The UCR plot proved to have 47% fewer berries weighing 48% less than the South Coast plot production. When plotted as cumulative totals (Figures 87, 88), the UCR production curve appeared to flatten out quickly when compared to the South Coast plot and berry production dropped to a trickle. Despite the large difference in yield, the average berry weights were comparable over the season (Figure 89) at Riverside and South Coast Field Station. This would appear to indicate that berries at both locations were of comparable size. The number of irregularly-shaped berries (arbitrary evaluation using the criteria set forth in the 1972 Final Report) produced at each location did not differ in any appreciable trend (Figures 90, 91).

Discussion

Ozone at relatively high concentrations (.30 ppm) caused a significant reduction in the number of berries produced in the fumigation study. A similar reduction was observed in comparing UCR and SCF test plots. Both the fumigation and the comparison of test plot harvest indicate that although yield is reduced in higher ozone levels, the berry size does not differ dramatically. The only area of dissimilarity was the lack of a discernible trend in the number of irregular berries produced by the test plots. The similarities between fumigation study and field test plots were striking but must not be taken as conclusive proof of ozone effects on strawberries in the field. Only a concerted field study could show the field effects, but it would not be feasible with a multiple harvest crop unless studied singly.

No major effects of ozone and PAN exposures were apparent in the levels of nutritional constituents in the berries.



Map 10. Locations of field and test plots of Tioga strawberries in the South Coast Air Basin.

Table 25. Summary of ozone effects on Tioga strawberries as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Total Berries Harvested			Total Weight		
Ozone	0	-	a[1]	A[2]	-	a	A
Treatments	.25	6.35	a	A	4.7	a	A
(ppm)	.30	38.07	b	B	32.41	b	B

		Average Berry Weight		Percent Irregular Berries		
Ozone	0	-	a	-	a	A
Treatments	.25	-	a	1.53	a	A
(ppm)	.30	-	a	-17.02[3]	a	B

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 26. Summary of the effects of PAN on nutritional constituents in Tioga strawberries as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Water	Solids	Nitrogen	Niacin	Riboflavin
PAN	0	- a[1]	- a	- a	- a	- a
Treatments	20	- a	- a	- a	- a	- a
(ppb)	40	- a	- a	- a	- a	- a

		Thiamine Microbiol	Calories	Carbohydrate	Thiamine Thiochrome
PAN	0	- a	- a	- a	- a
Treatments	20	- a	- a	- a	- a
(ppb)	40	- a	- a	- a	- a

		Vitamin C	Ash	Fiber	Protein	Cu
PAN	0	- a	- a	- a	- a	- a
Treatments	20	- a	- a	- a	- a	- a
(ppb)	40	- a	- a	- a	- a	- a

		Sr	Mn	Fe	Zn
PAN	0	- a A[2]	- a	- a	- a
Treatments	20	1.08 a A	- a	- a	- a
(ppb)	40	-50.11[3] b B	- a	- a	- a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 27. Summary of the effects of ozone on nutritional constituents in Tioga strawberries as shown by percent reduction from the control treatment and the analysis of variance coupled with Duncan's multiple range test.

		Solids	Water	Protein	Ash	Fiber
Ozone	0	- a[1]	- a	- ab A	- a	- a
Treatments	.20	- a	- a	-10.4 a A	- a	- a
(ppm)	.35	- a	- a	9.6 b A	- a	- a

		Niacin	Nitrogen	Carbohydrate	Calories
Ozone	0	- ab A	- ab A	- a	- a
Treatments	.20	-13.04 a A	-10.0 a A	- a	- a
(ppm)	.35	-16.52 b A	10.0 b A	- a	- a

		Thiamine: Thiochrome	Thiamine: Microbiol	Vitamin C	Riboflavin
Ozone	0	- a	- ab A	- a	- a
Treatments	.20	- a	-4.51 a A	- a	- a
(ppm)	.35	- a	3.759 b A	- a	- a

		Pb	Rb	Sr	Mn	Fe	Cu	Zn
Ozone	0	- a	- a	- a	- a	- a A	- a	- a
Treatments	.20	- a	- a	- a	- a	-10.34 a A	- a	- a
(ppm)	.35	- a	- a	- a	- a	-113.14 b B	- a	- a

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Figure 85. Comparison of the total weight of Tioga strawberries picked per harvest at SCFS (open circles) and UCR (solid circles) at harvest oxidant dosages.

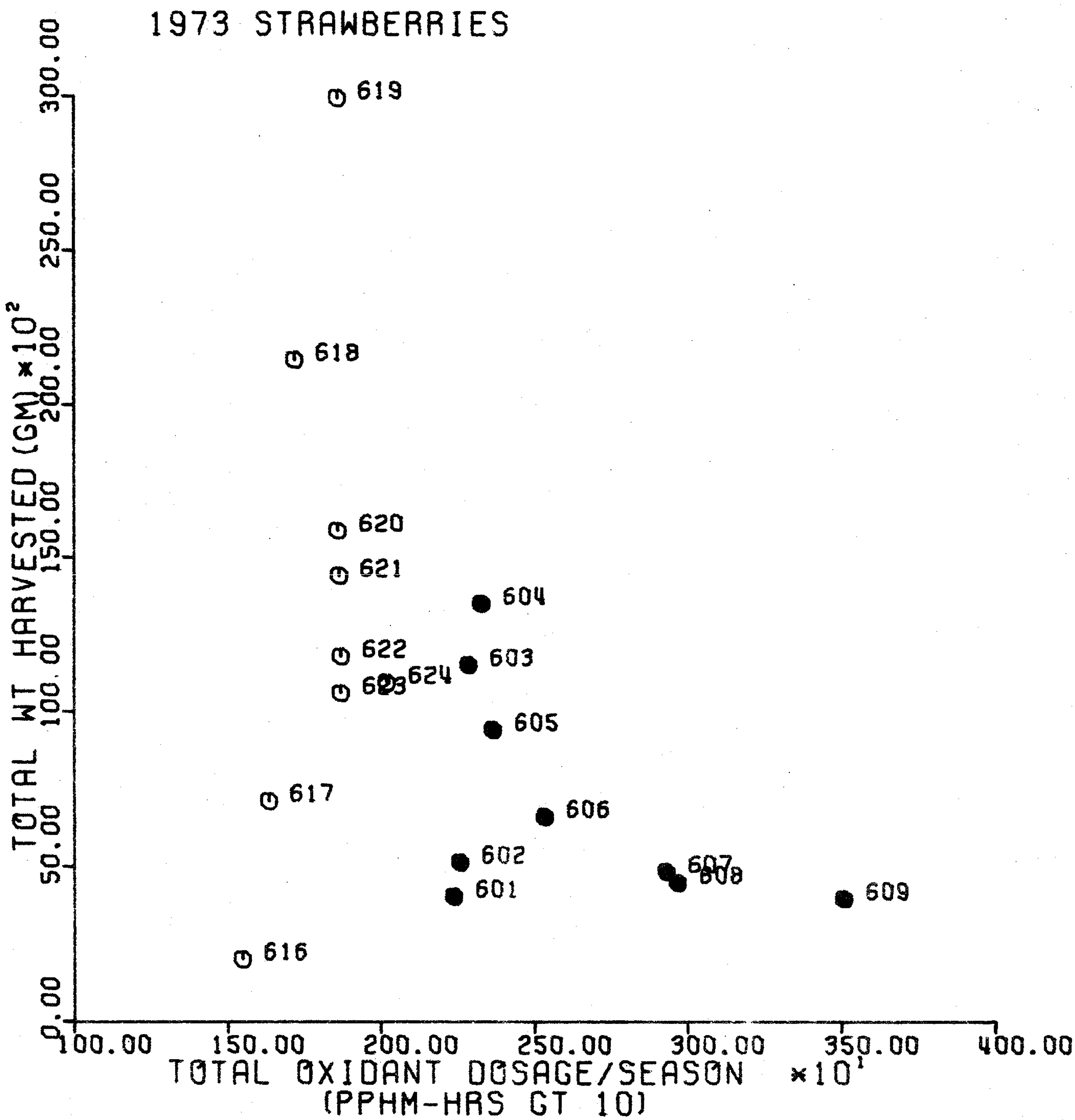


Figure 86. Comparison of the total number of Tioga strawberries picked per harvest at SCFS (open circles) and UCR (solid circles) at harvest oxidant dosages.

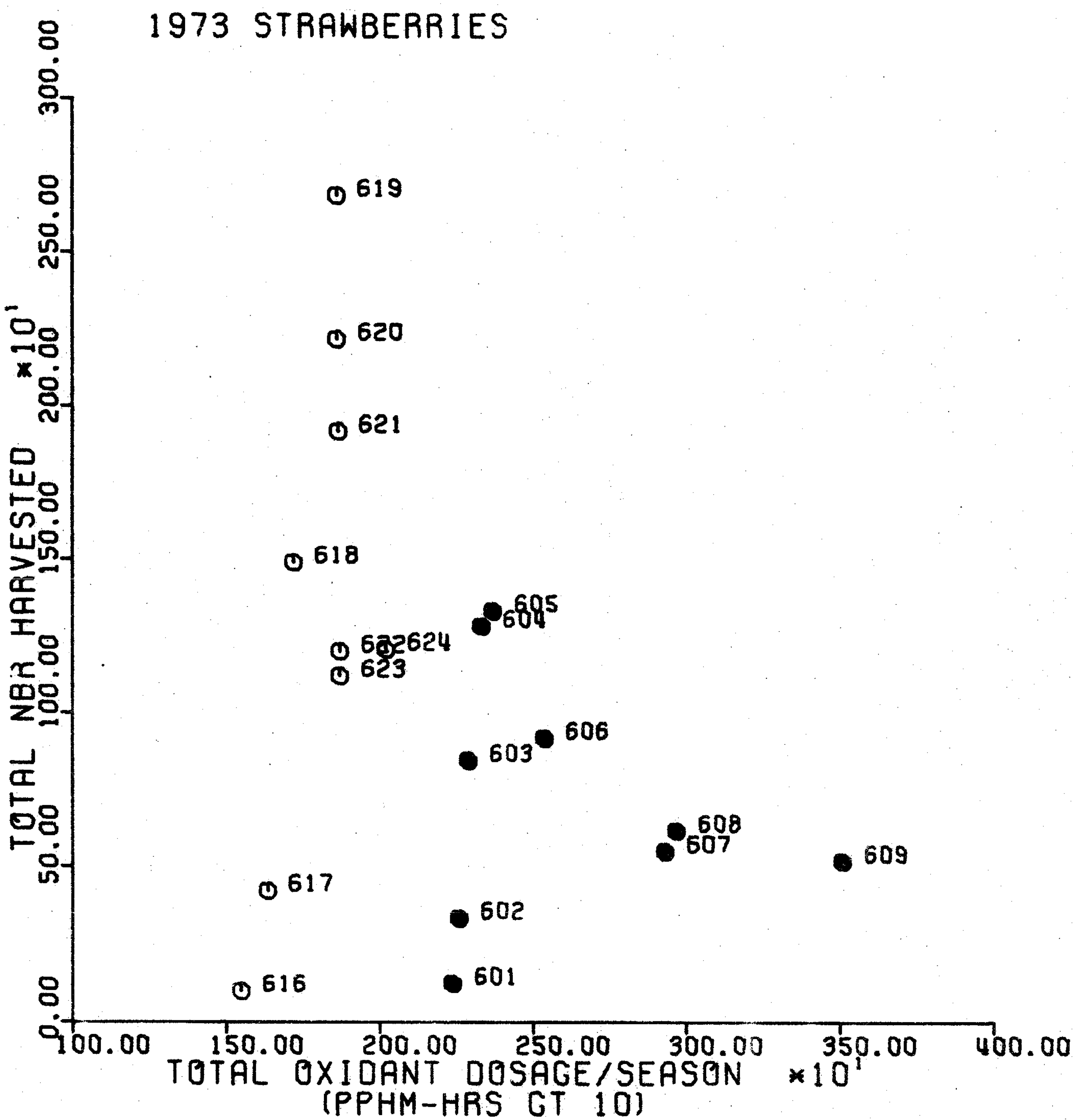


Figure 87. Comparison of the cumulative number of Tioga strawberries harvested at SCFS (open circles) and UCR (solid circles) at harvest oxidant dosages.

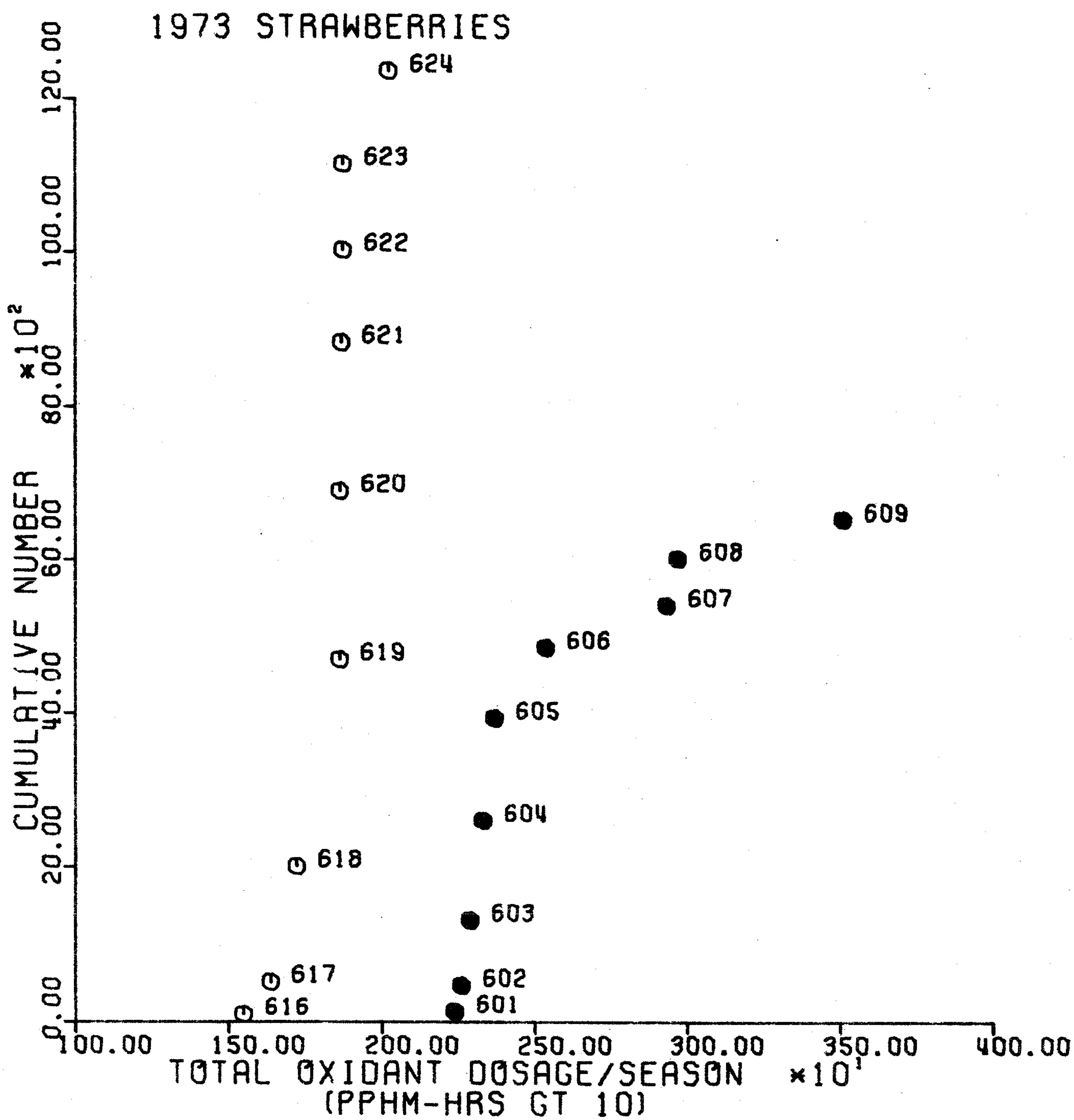


Figure 88. Comparison of cumulative weights of Tioga strawberries harvested at SCFS (open circles) and UCR (solid circles) at harvest oxidant dosages.

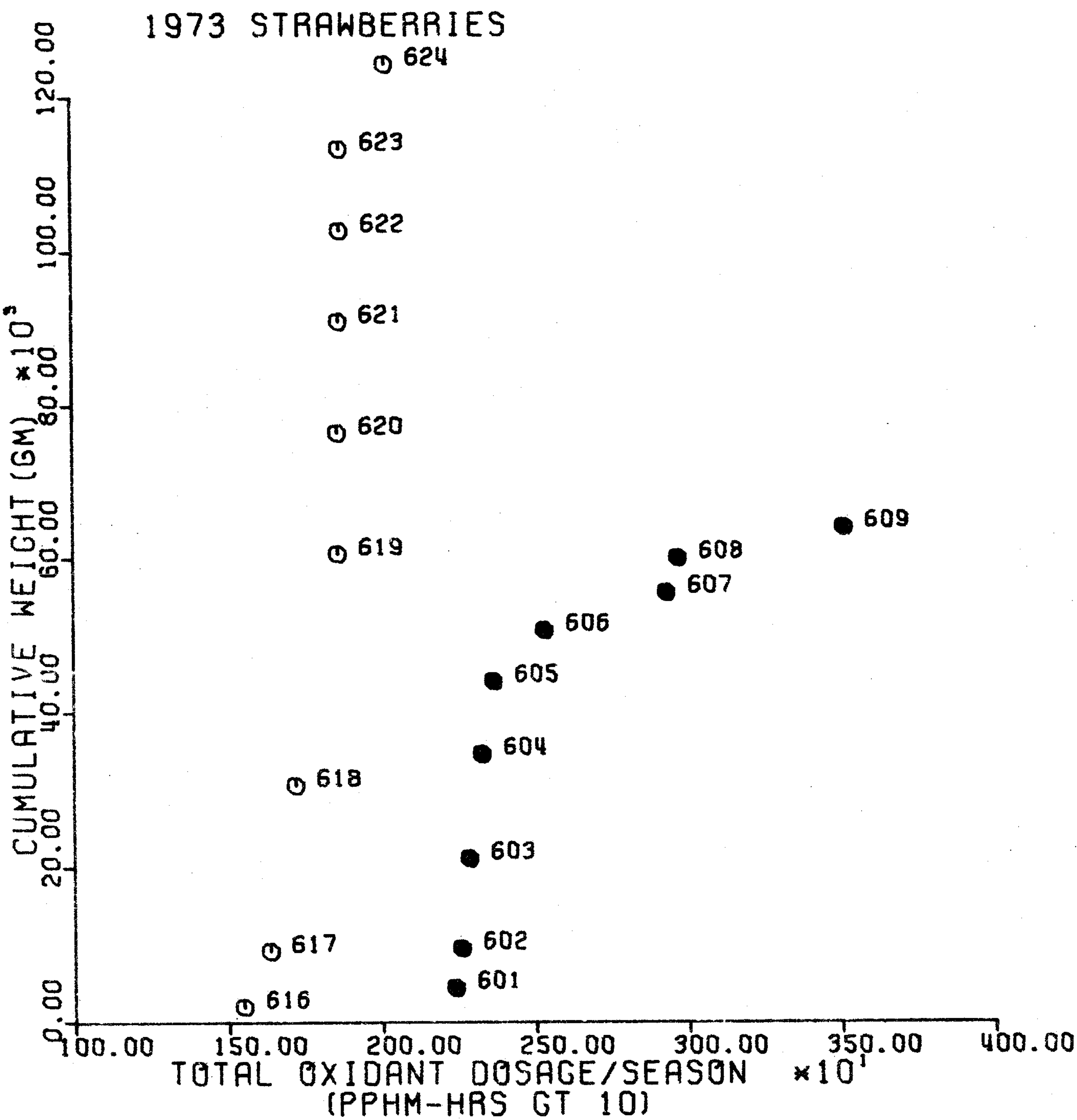


Figure 89. Comparison of the average berry weight per harvest at SCFS (open circles) and UCR (solid circles) at harvest oxidant dosages.

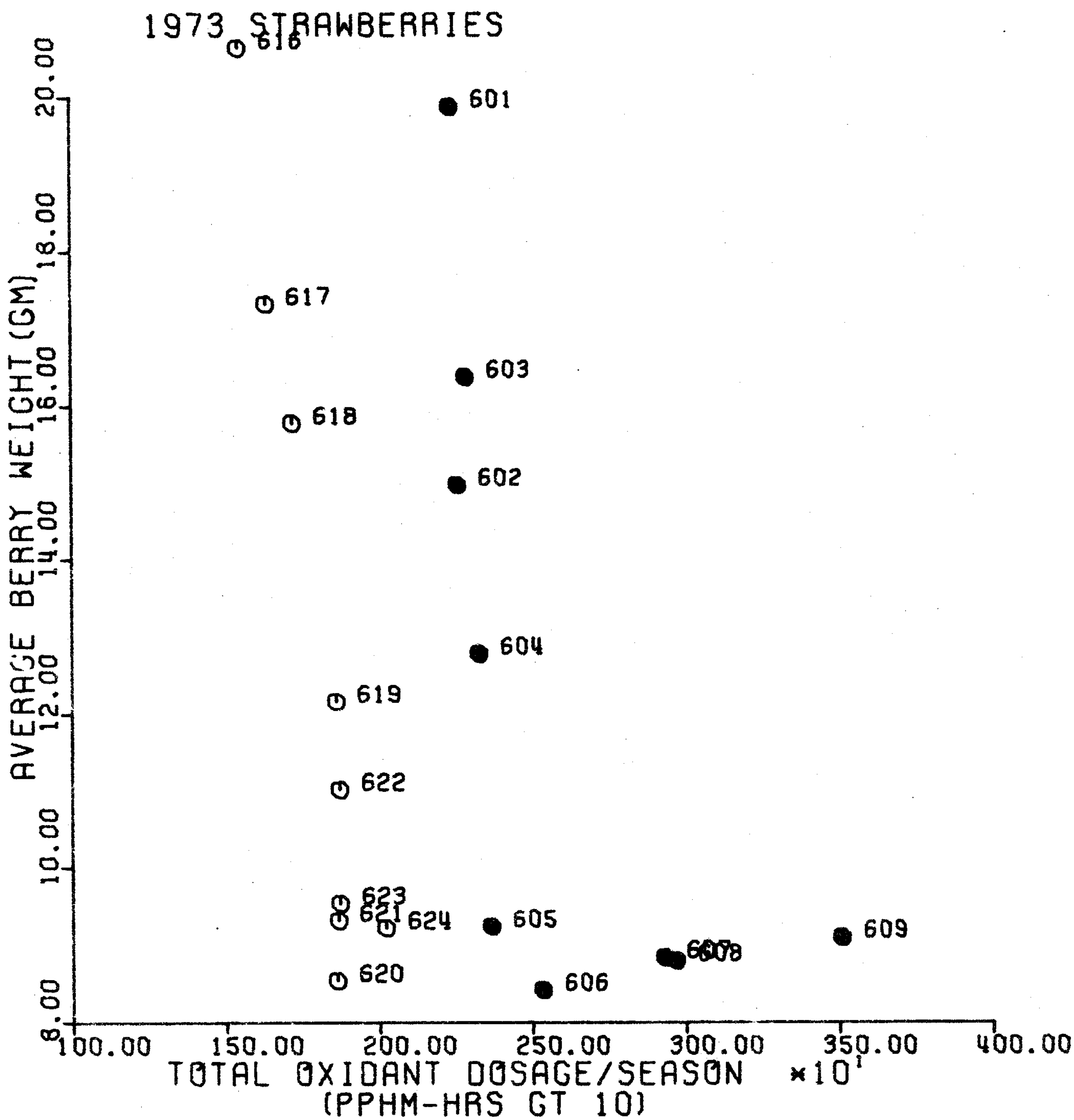


Figure 90. Plot of percentage of irregular Tioga strawberries harvested at SCFS with total ambient oxidant dosage present during growth.

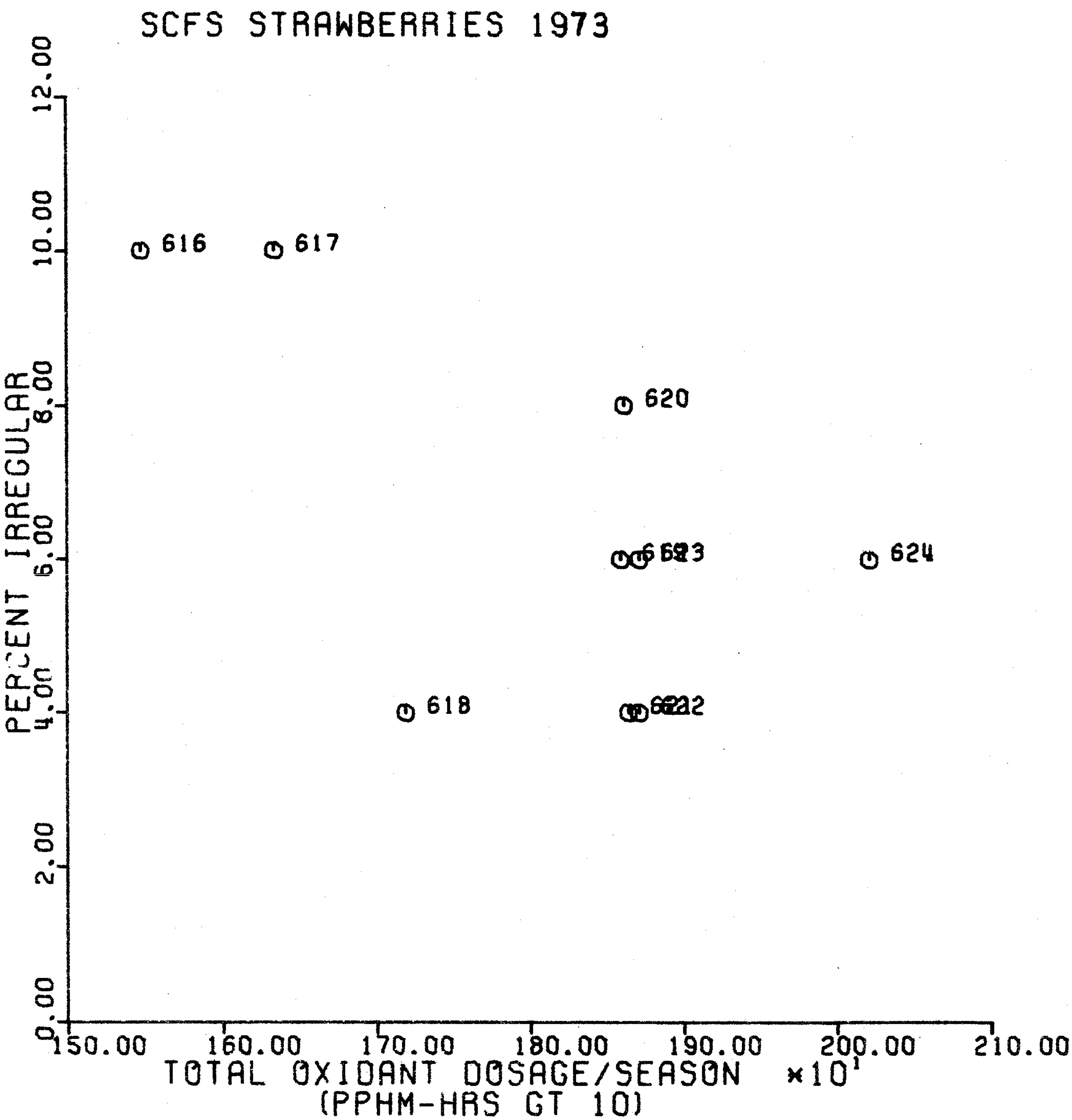
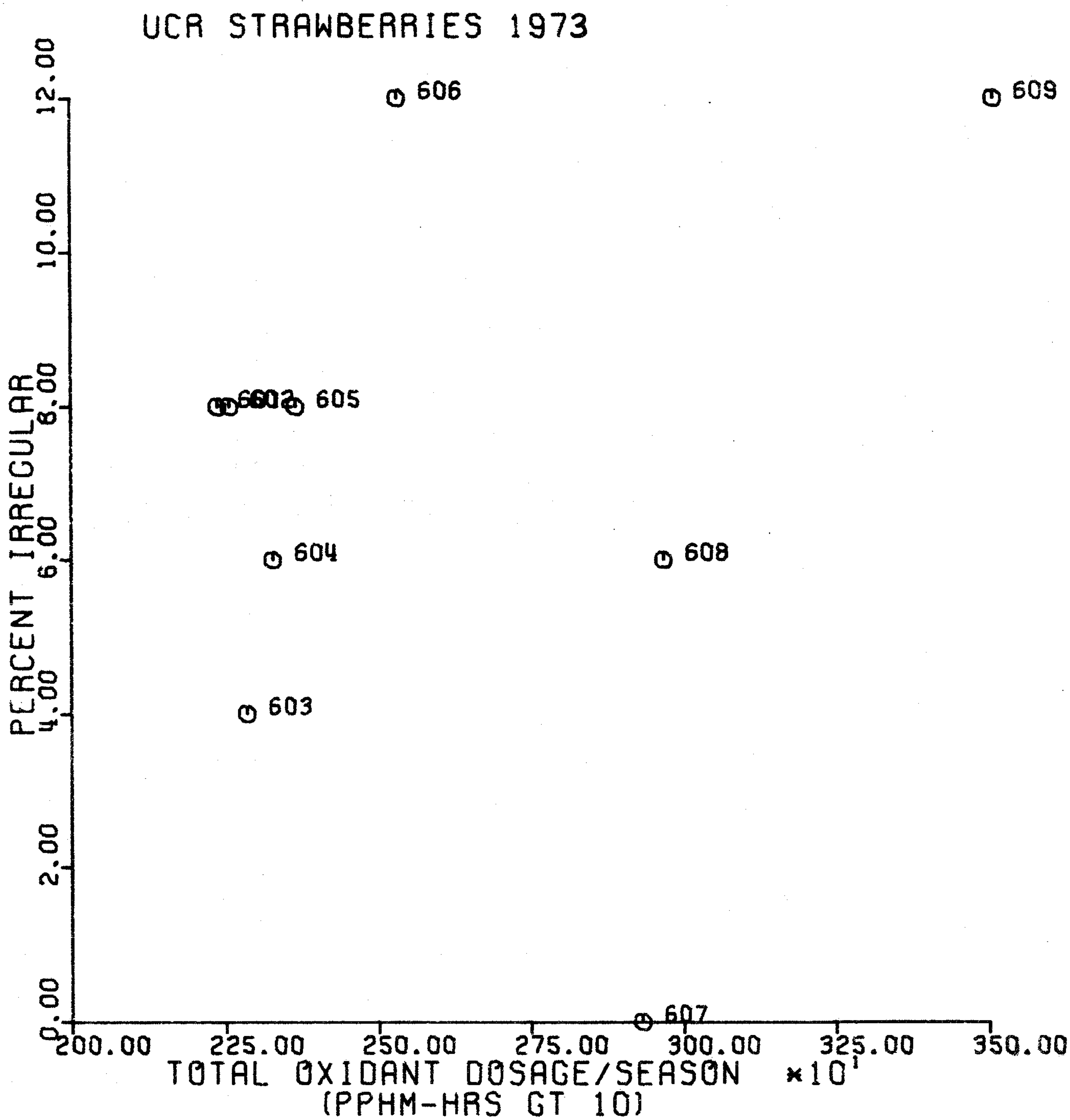


Figure 91. Plot of percentage of irregular Tioga strawberries harvested at UCR with total ambient oxidant dosage present during growth.



VALENCIA ORANGE

Introduction

The same groves used in the 1973 quality study were utilized in this year's program. All trees were Valencias on troyer rootstock 10 to 14 years old. Data was obtained from packing house records on a field-boxes per grove basis and recalculated to field-boxes per tree yield.

Field Study

Locations: Ten commercial groves were monitored in this study in a four-county area (Map 11).

Sampling Techniques: Grower permission was obtained to use data starting with the initial harvest to the present season.

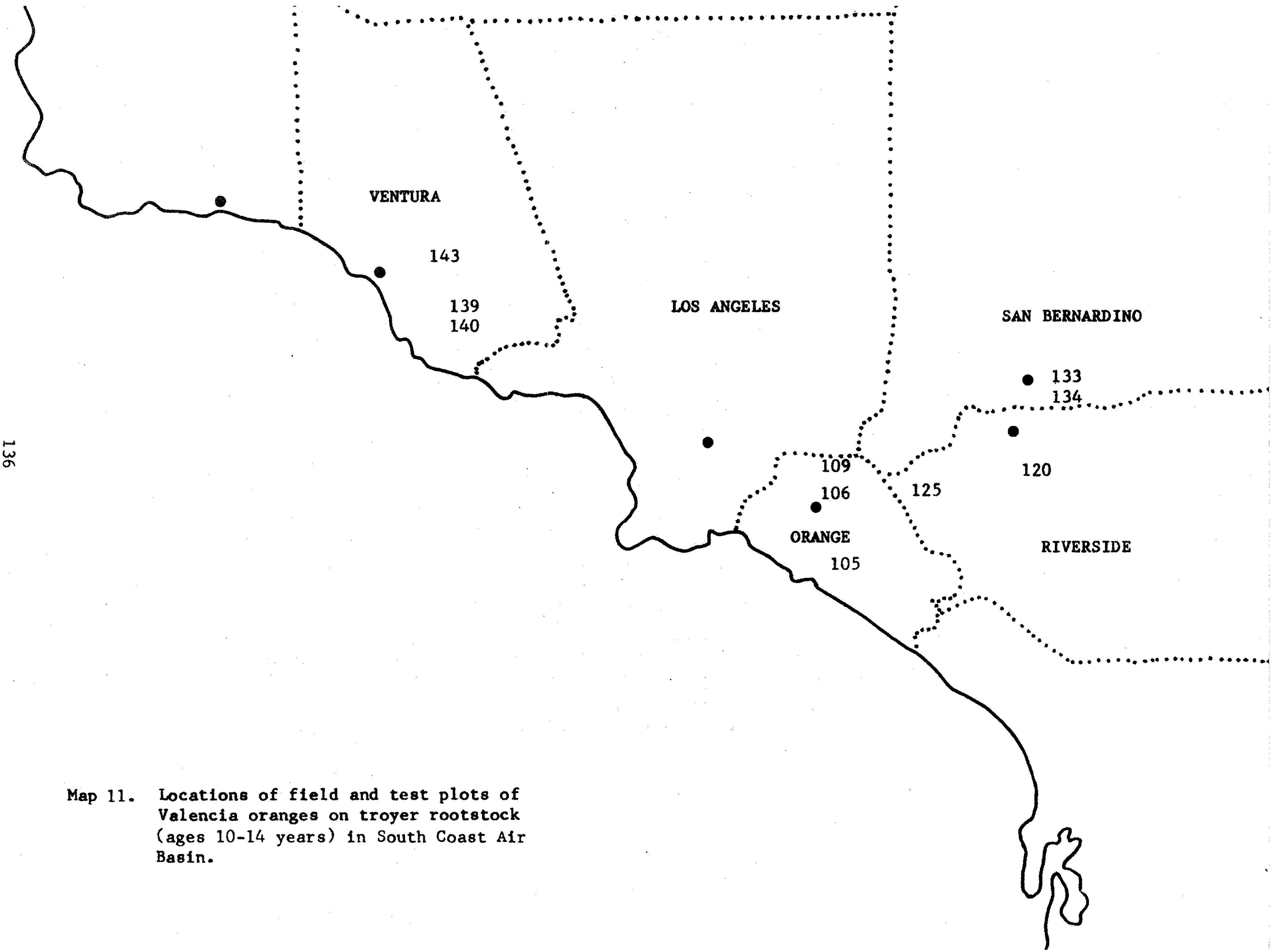
Results: Correlation of the yield in field-boxes per tree and ozone dosage was conducted for the 1972 and 1973 seasons (Figures 92, 93). Neither year's dosage-yield correlations was found to be significant.

Plots of yearly yields were constructed to determine whether any obvious trends in bearing were evident (Figures 94 - 97). These plots illustrate the alternate bearing nature of Valencias very well but show little else. The Ventura County groves appear to be accelerating production over most other counties but whether this is due to lower air pollution can only be speculated. The correlations of ozone dosage and yield failed to confirm this.

Discussion

The use of field boxes was found to be a poor unit for measuring yields. No size ratings or fruit count were available and the number fruit per field-box could vary dramatically with size. Comparisons between locations were therefore prone to a great margin of error and correlations with ozone may not be indicative of the true relationship.

This type of study should be much more extensive with controls limiting as many variables as possible if it is to be effective. Tree crops, because of their age-harvest requirements, would require a long-term program over a number of bearing years to come up with definitive results. The cost of such a program would be great when compared to annual table crops but should be undertaken if the effects of ozone are to be observed.



Map 11. Locations of field and test plots of Valencia oranges on troyer rootstock (ages 10-14 years) in South Coast Air Basin.

Figure 92. Correlation of number field boxes per tree harvested in 1972 with the total ambient dosage present during growth.

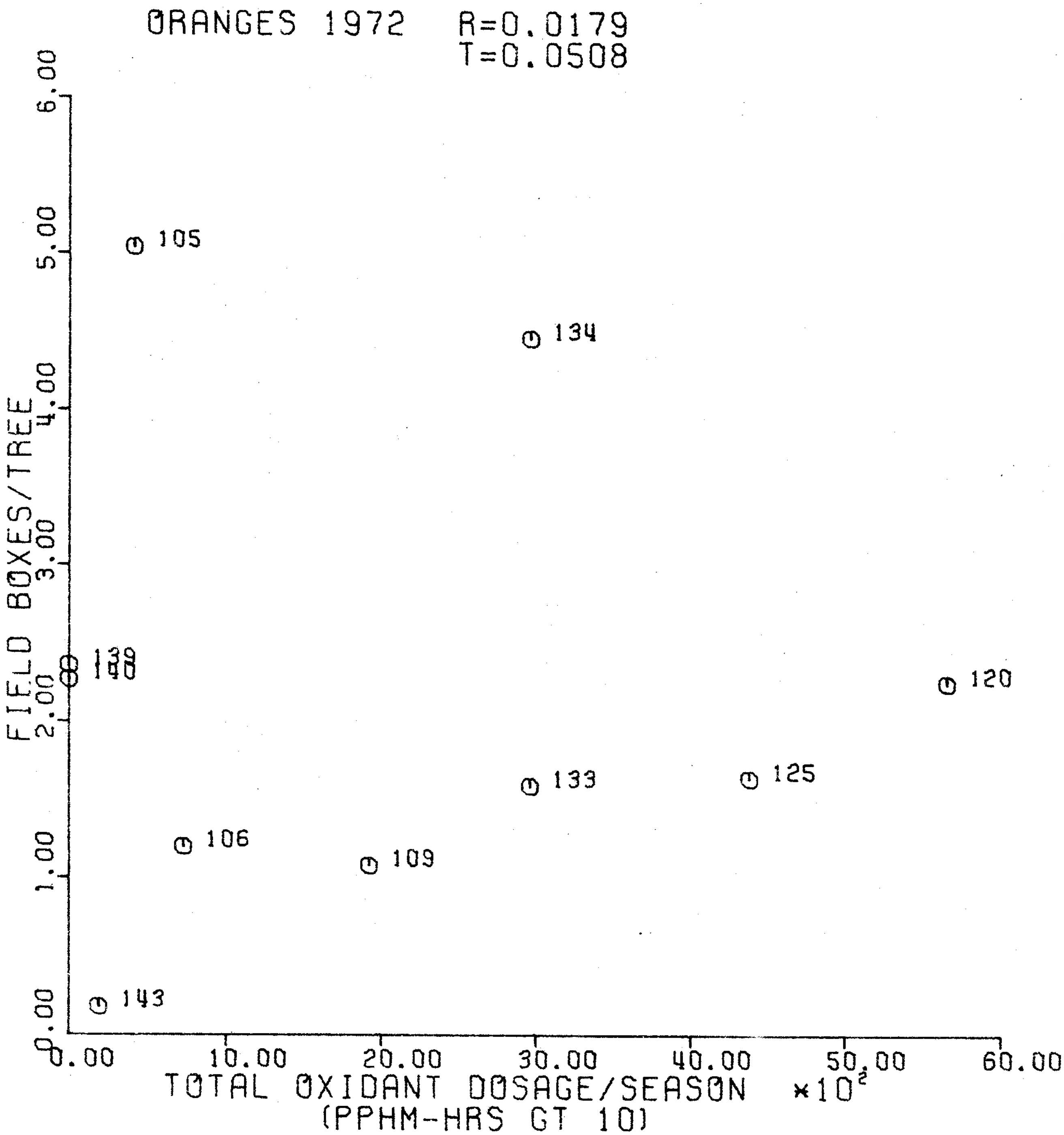


Figure 93. Correlation of number field boxes per tree harvested in 1973 with the total ambient dosage present during growth.

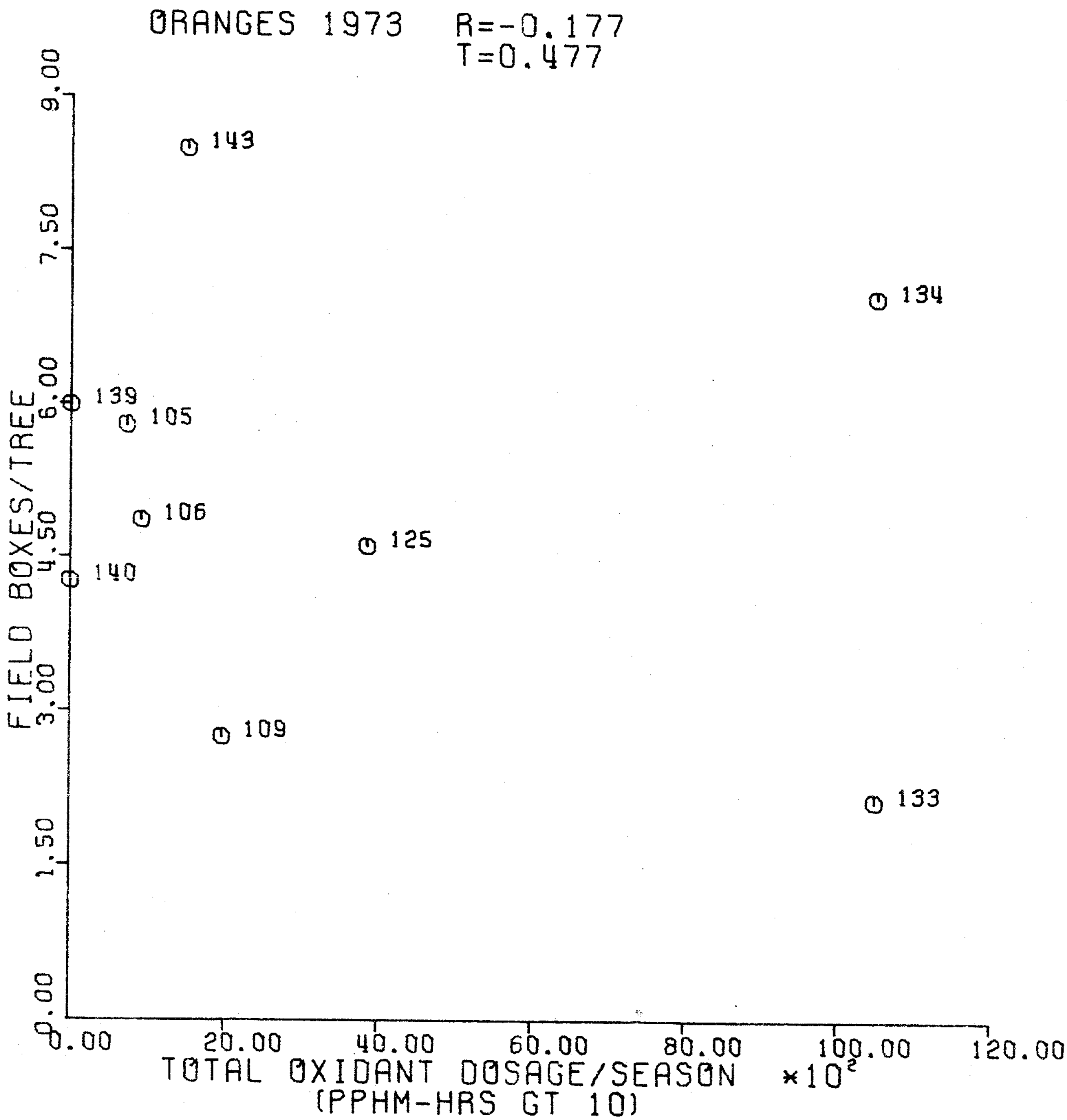


Figure 94. Plot of yearly Valencia orange yield in field boxes/tree for Riverside County.

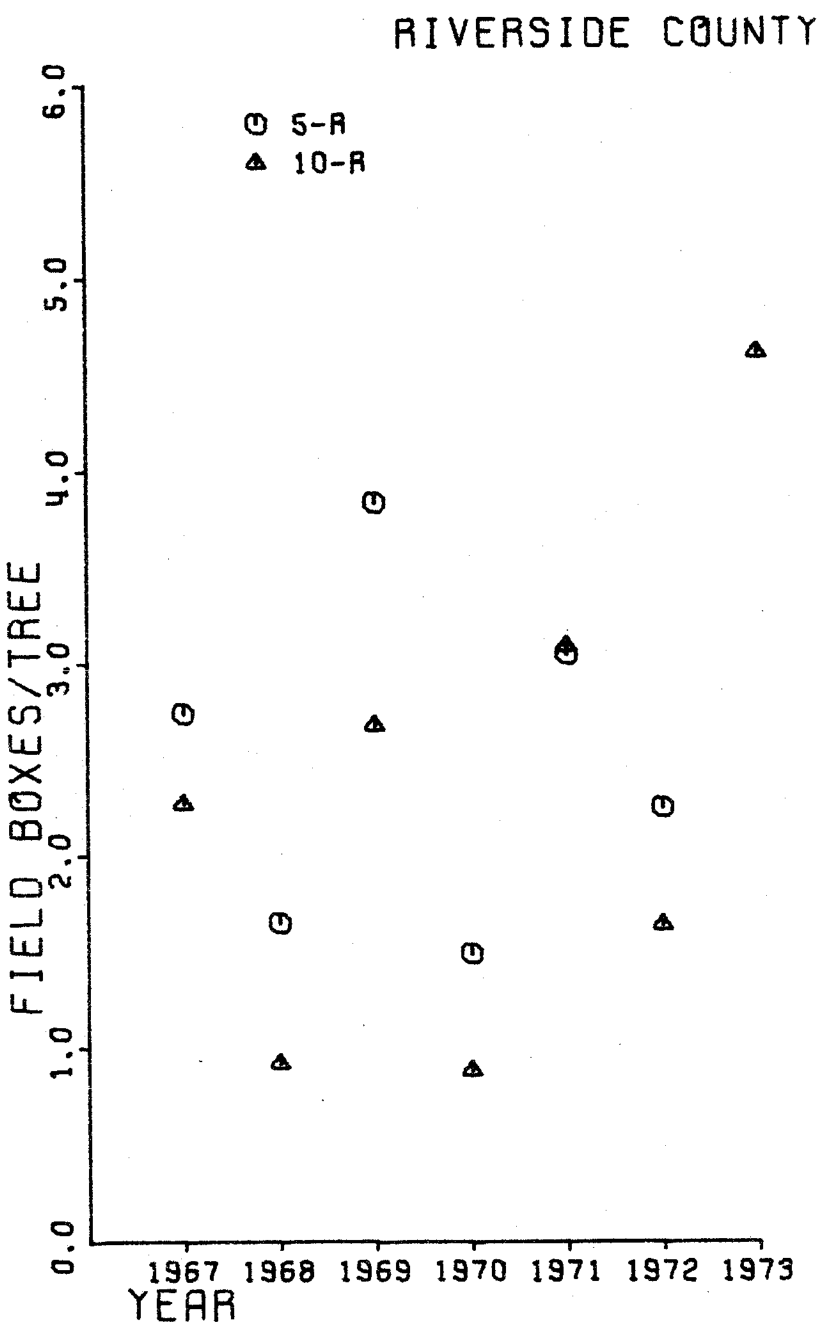


Figure 95. Plot of yearly Valencia orange yields in field boxes/tree for Orange County.

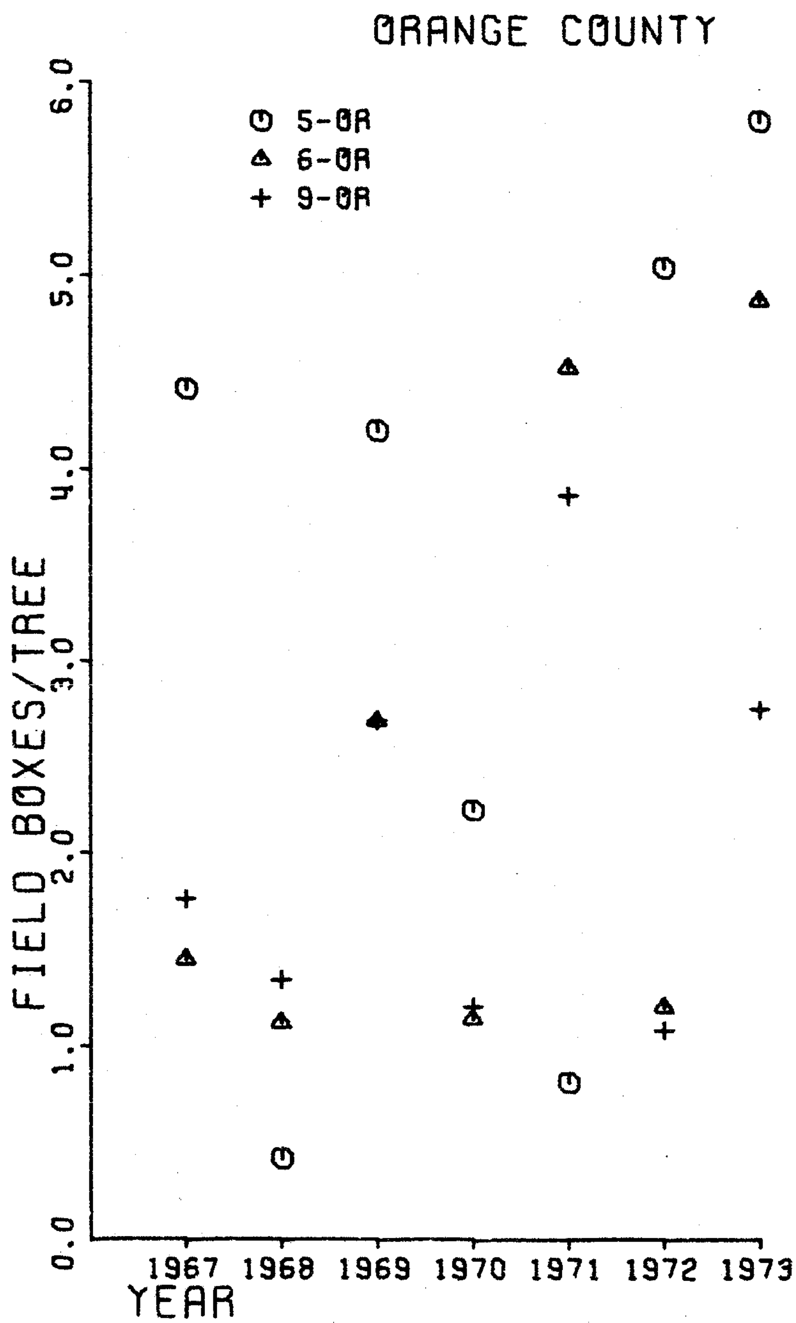


Figure 96. Plot of yearly Valencia orange yields in field boxes/tree for Ventura County.

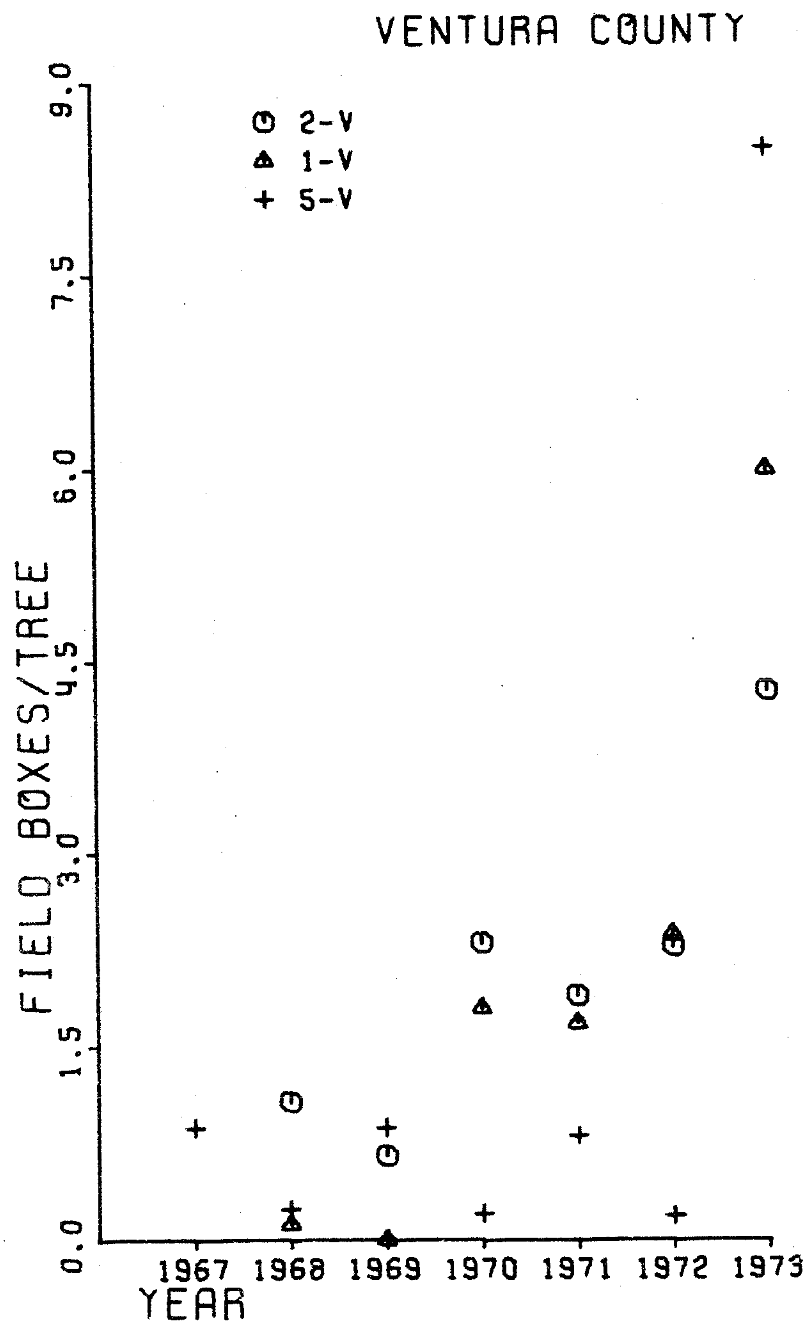
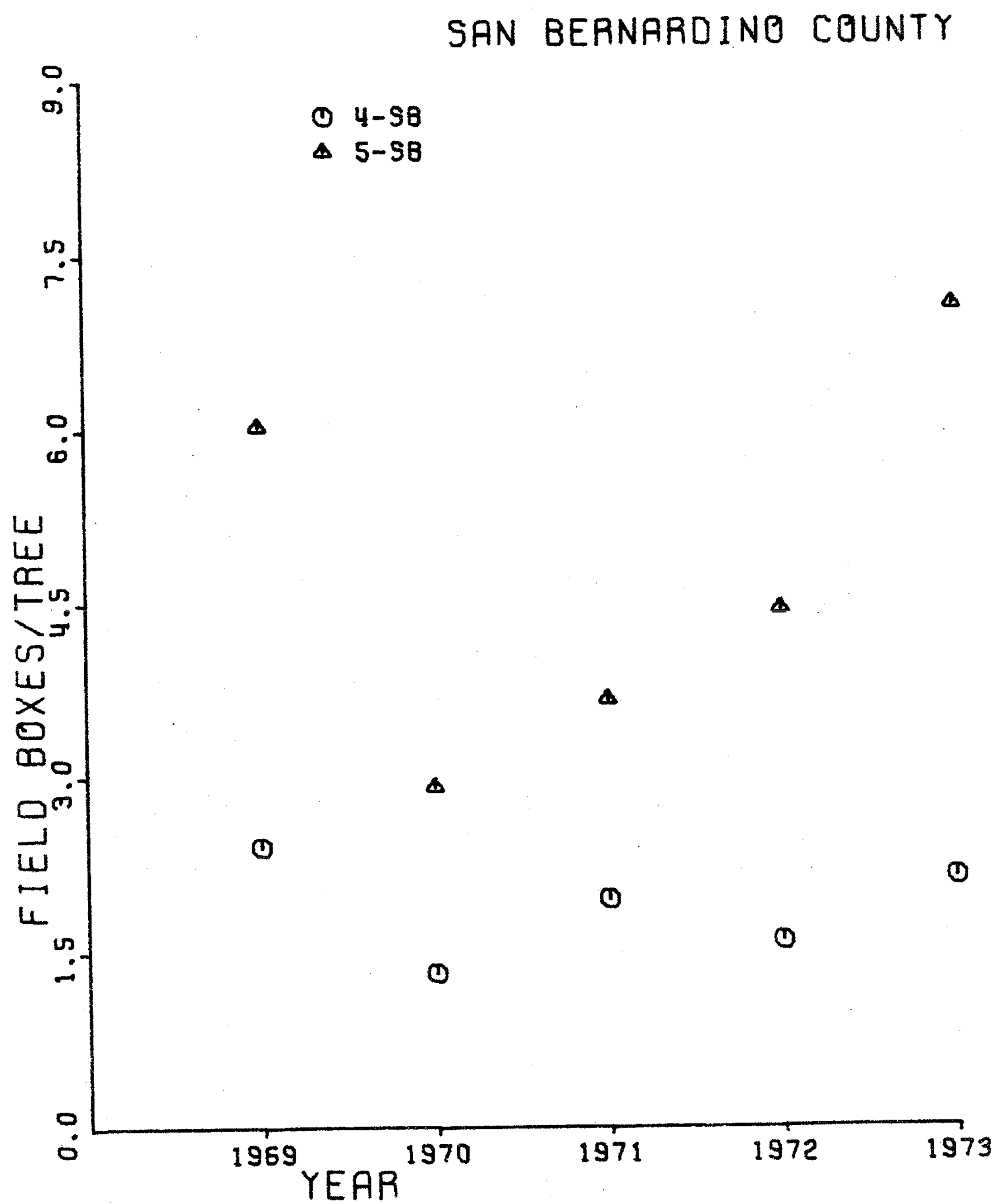


Figure 97. Plot of yearly Valencia orange yields in field boxes/tree for San Bernardino County.



DISCUSSION

The prototype ozone dosage-crop loss conversion function completed for sweet corn represents the first crop loss assessment methodology with the potential for making accurate standardized loss estimates. When completed it would represent an acceptable means of collecting annual crop loss assessments for a geographical region. This type of data is desparately needed to establish viable secondary air quality standards to protect California's agricultural industry.

Sweet corn was selected as a developmental test crop because of its wide distribution and low man-hour requirements. The multiple harvest crops (tomato and strawberry) presented impossible logistical problems in harvesting several times a week over an extended season and evaluating harvested produce. The man-hour limitations of our program precluded using such crops. The root crops (carrot) was not selected because the effects of crowding and competition could not be standardized and experiments on individually grown plants would not produce results applicable to the field. Cabbage was found to be extremely resistant to ozone and lettuce too sensitive to ozone, PAN, and the homologues of PAN. Each was poorly distributed throughout the air basin and offered too few field locations.

PAN appeared to have little effect on the nutritional levels of cabbage, corn and strawberries but did influence carrots, lettuce and tomatoes. In most instances, exposures were observed to increase the levels of nitrogen and vitamin constituents in what might be an injury reaction. However, the association between increasing nutritional levels and increasing PAN concentrations was poor. The low fumigation level (.20 ppb) seemed to induce most effects. Only the lettuce samples had consistently elevated levels of solids, nitrogen and vitamin C. There appeared to be no general trend in the reaction of nutritional constituents to PAN exposures.

Significant reductions in the levels of solids and carbohydrates within corn and tomatoes appeared to be associated with ozone exposures. The vitamin levels fluctuated among treatments of the seven crops but no discernible trend was evident. Levels of constituents within harvested carrot roots and strawberries were least affected by ozone exposure and showed significant differences in only a few categories. Copenhagen Market cabbage was observed to have significant increases in solids, fiber, carbohydrates, vitamin C, and thiamine, as a result of ozone exposures. This apparent stimulation was contrary to results recorded for the other six crops.

It should be noted that the nutritional results were compiled from the analyses of only five replicates per treatment and may therefore be prone to excessive error. They are presented to indicate possible effects of ozone but are not definitive. Many of the reductions in nutritional levels associated with ozone exposures were somewhat predictable based on past experimental work. Other apparent ozone-induced increases in constituent levels are contrary to what was expected and cannot be explained.

A comparison of the 1972 and 1973 ozone fumigation testing the effect of frequency of ozone exposure during long-term fumigation proved to be dramatic, especially on tomatoes and sweet corn. Ozone leaf injury occurred during both years' fumigations but no yield reductions were observed in the 1973 fumigation (1½ 6-hour exposures per week). Ozone effected measurable reductions in the size (tomatoes) and weights of fumigated plants but did not influence yields. More frequent exposures for shorter periods (3 3-hour exposures per week) in 1972 produced significant reductions in plant size and also in yields. It is entirely possible that the frequency of exposure may represent an additional variable which may significantly influence effects and should be standardized when fumigation results are compared.

The AMBI plant indicator system proved to be a reliable monitoring system for ozone and PAN during its replicate year of testing. The major environmental variables tested did not significantly influence injury. Pollutant dosage was the only significant factor affecting damage. The only question left unresolved was the functional relationship involved. The 1972 study indicated that a curvilinear relationship (parabola) was more significant than a linear regression. The 1973 data, however, was only significant using a linear regression. The functional relationship appears questionable although linear regressions were significant both replicate years.

The November 1973 smog episode raised significant questions as to the effectiveness of the existing air monitoring network in the State. PAN, PPN or both were primarily responsible for the loss of the November leaf lettuce crop in Orange County yet are not monitored by the existing instrument network. Most leafy crops (endive, beets, parsley, Swiss chard) were also heavily damaged or lost. High PAN levels usually do not occur within the peak ozone season and affect fall and spring grown crops. If secondary air quality standards are to be established, much more information relating to PAN injury thresholds must be obtained.

REFERENCES

1. Brennan, E., I. A. Leone, and P. M. Halisky. 1969. Response of forage legumes to ozone fumigations. Phytopathology 59:1458-1459.

2. Brennan, E., and P. M. Halisky. 1970. Response of turfgrass cultivars to ozone and sulfur dioxide in the atmosphere. Phytopathology 60:1544-1546.

3. Heagle, A. S., D. E. Body, and E. K. Pounds. 1972. Effects of ozone on yield of sweet corn. Phytopathology 62:683-687.

4. Jaffe, L. S. 1967. Effects of photochemical air pollution on vegetation with relation to the air quality requirements. J. Air Pollut. Contr. Ass. 17:38-42.

5. Noble, W. M., and L. A. Wright. 1958. Air pollution with relation to agronomic crops: II. A bio-assay approach to the study of air pollution. Agron. J. 50:551-553.

6. Oshima, R. J. 1973. Effect of ozone on a commercial sweet corn variety. Plant Dis. Reptr. 57(9):719-723.

7. Oshima, R. J. 1973. Final Report -- Development of a system for evaluating and reporting economic crop losses caused by air pollution in California: I. Quality study. State of Calif., Dept. Food and Agr., Sacramento, California. 131 pp.

8. Thompson, C. R. 1968. Effects of air pollutants on lemons and navel oranges. Calif. Agr. 22(9):2-3.

9. Thompson, C. R. 1969. Effects of air pollutants in Los Angeles basin on citrus. Proc. 1st Int. Citrus Symp. Vol. 2.

PUBLICATIONS

1. Oshima, R. J. 1973. Effect of ozone on a commercial sweet corn variety. Plant Dis. Reptr. 57(9):719-723.

2. Oshima, R. J. 1974. A viable system of biological indicators for monitoring air pollutants. J. Air Pollut. Contr. Ass. 24(6):576-578.

APPENDIX A

SEVERE AIR POLLUTION EPISODE IN SOUTH COAST BASIN[1/]

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The photochemical air pollution episode that occurred between November 8 and 11, 1973, in the south coast air basin of California, was unusual because the accompanying weather conditions and the resulting injury to vegetation did not fit into the pattern normally associated with attacks of ozone and peroxy acetyl nitrate (PAN). The injury to leafy vegetables was worse than usual, considering the concentration of phytotoxicants measured.

Severe injury was observed on vegetable crops in the coastal plain of Los Angeles and Orange counties, and less severe injury was observed in the inland valleys of San Bernardino and Riverside counties. Injury, particularly on leaf lettuce, also occurred in the agricultural areas on the plateau southeast of Riverside, near Moreno.

Staff members from Agricultural Commissioners' offices in the four counties sharing the south coast basin, and representatives from the Air Pollution Program of the State Department of Food and Agriculture surveyed the area to estimate the extent of the damage. Mature Boston leaf lettuce in Orange County was reported to be unmarketable after the pollutant attack. In Los Angeles and San Bernardino counties, injury was heavy, but with extensive trimming much of it could be marketed. Immature lettuce throughout the basin was severely injured, but prospects of full recovery were good if no further attacks occurred. Other crops severely injured were romaine lettuce, Swiss chard, endive, parsley, and beets.

In general, the symptoms were of the type attributed to PAN, but the overall syndrome differed sufficiently to make it apparent that the incident was unique. On Boston lettuce the injury was confined largely to 1- to 3-inch bands around the exposed leaf margins on leaves of all ages. The effect was primarily leaf collapse or "burn," which ultimately turned brown and covered the entire head. Normally PAN injury is confined to leaf tissue of a precise age or stage of growth and consequently develops on only a few leaves following a single exposure. But in this incident, large areas of leaves on Swiss chard and other plants collapsed, and injury symptoms developed which were not attributable to ozone or PAN. In most areas the injury was far more severe than that produced previously from comparable concentrations of total oxidant and PAN.

Oxidant concentrations

Concentrations of oxidants differed markedly from one region to another. On November 10, at the University of California's Riverside monitoring station, the highest total oxidant reading was 0.17 ppm, sufficient to cause light plant injury. At the South Coast Field Station in Orange County, the highest reading of 0.47 ppm was considered severe. During the same period,

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PAN maximum at U. C. Riverside was recorded at 16 ppb, sufficient for light plant injury, while at Garden Grove the highest reading was 30 ppb. PAN concentrations remained above 7 ppb for 40 continuous hours from 1:00 a.m. on November 9 to 5:00 p.m. on November 10. Photochemical oxidants rarely survive through the night, and such a long period of elevated levels has not been reported previously.

On November 9, 10 and 11, after the PAN peak, the automated electron capture chromatograph (PAN-alyzer) recorded another peak which coincided with the retention time for peroxypropionyl nitrate (PPN). This was strong evidence that toxic levels of PPN, a homologue of PAN, were present. The PAN-alyzer was not calibrated for accurate measurement of PPN, but comparison with an instrument at U. C. Riverside which has previously been calibrated for PPN indicated that a maximum concentration of about 8.5 ppb was reached and persisted for about three hours. On November 10, estimated concentrations exceeding 4 ppb were recorded continuously for 16 hours; and during the three days, concentrations of about 4 ppb were recorded for a total of 32 hours. Traces of PPN have been detected at U. C. Riverside, but measurable levels have not been recorded.

Phytotoxicity of synthesized PPN has been tested on several occasions by exposing seedlings of petunia, barley, tomato, bean and other plants to PPN under controlled conditions. In all instances PPN was from seven to ten times more toxic than PAN under comparable conditions.

The unusual response of plants to the recent smog attack has stimulated speculation about the possibility of an unidentified new phytotoxicant. This is a distinct possibility, but many other factors must also be considered in evaluating the episode. In Orange County, where the most severe injury occurred, the smog contained a mixture of PAN, PPN, and ozone. Elevated levels of toxicants persisted continuously for up to 40 hours.

Another possible explanation is that susceptibility of plant tissues may have been increased significantly by favorable weather conditions before and during the prolonged exposure. During two of the four days when severe plant injury occurred, records from Riverside and Orange counties showed a continuous overcast condition: maximum relative humidity ranged from 66% to 88%; minimum relative humidity was from about 50% to 60%. On November 11, the last of the pollution attack, relative humidity dropped to 34% in Orange County and to 41% in Riverside. Maximum temperatures at both locations were between 70°F and 80°F, and minimum temperature ranged from the mid-40s to the mid-50s. These weather conditions are favorable for rapid growth of vegetables which suffered injury -- and may have been responsible for the for the production of exceptionally susceptible leaf tissue.

As has been suggested, it is entirely possible that a new toxicant developed in the polluted atmosphere, perhaps in response to changes in primary pollutants being discharged. A more probable explanation of the sudden exceptionally severe symptoms may be that elevated levels of a mixture of ozone, PAN and PPN invaded the area during a period when the climate was particularly favorable for maximum plant susceptibility. It is also possible that additional compounds related to PAN and PPN may occasionally add to the toxicant complex. Controlled experiments with peroxybutyryl nitrate (PBN) have indicated it to be approximately twice as toxic as PPN. No analyses for additional compounds were made during this episode.